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SOUTHERN HEMISPHERE GLACIER ATLAS

by

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FOREWORD

Regions of forbidding terrain and climate are acquiring an increasing significance in present-day military planning. Mountain glaciers with their associated climates constitute one such adverse environment in which military units require special equipment and techniques. Much information is available about the glaciers of the world and, in 1958, a D/A contract was awarded the American Geographical Society to assemble this information in a form accessible to military users. As a result of that contract an atlas of mountain glaciers in the Northern Hemisphere was published showing the distribution of a special type of environment that military forces may encounter in many parts of the world.

In November 1963 the Office, Chief of Research and Development, Dept. of the Army, Washington, D.C., sponsored a contract with the American Geographical Society for a similar study of mountain glaciers of the Southern Hemisphere. Technical monitorship of the contract was furnished by the Regional Environments Branch of the Earth Sciences Division. Dr. William O. Field, Department of Exploration and Field Research, American Geographical Society, served as the project officer and the chief researcher was Dr. John M. Mercer. Under contract DA49-092-ARO-39, "Glacial Atlas and Text: Northern Hemisphere," the American Geographical Society is currently updating the study of northern hemisphere glaciers. The report will be published by these Laboratories.

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ABSTRACT

This study is a literature survey of knowledge on mountain glaciers in the Southern Hemisphere. The Southern Hemisphere is divided into the following regional categories with respect to glaciers: (1) The Andes of South America, (a) Ecuador, (b) Peru, (c) Bolivia, (d) Chile, and (e) Argentina, (2) New Guinea, (3) East Africa, (4) Sub-Antarctic Islands, (5) New Zealand, and (6) Antarctica. Included are discussions on the distribution, extent, characteristics, and behaviour of mountain glaciers and an extensive list of references for each regional discussion. A history of observations and current research programs is incorporated in the text. Nineteen new maps have been prepared on the mountain glaciers in the Southern Hemisphere.

PREFACE

In the Southern Hemisphere mountain glaciers are found in South America, Africa, New Guinea, New Zealand, Antarctica, and several islands in the Sub-Antarctic. This report is believed to represent the first effort to compile a comprehensive review of their distribution, characteristics, and variations along with extensive reference lists of source materials. It is hoped that it will stimulate further effort in correlating existing information and will contribute to a better understanding of the dynamics of glaciation, both in the local area and in relation to the rest of the world.

The information for many areas in the Southern Hemisphere is fragmentary and much of it is scattered among relatively obscure foreign-language sources and in the accounts of mountaineers and observant travelers. Inevitably, considerable interpretation and evaluation has been required of the author, Dr. John Mercer, who is not only familiar with the literature but has also carried out glaciological observations in parts of the Southern Andes, New Zealand, and Antarctica. He has assembled this report over a period of eighteen months at the American Geographical Society's Department of Exploration and Field Research from the files of the World Data Center A: Glaciology and the Society's library and map collections. Information was also obtained from the library of the American Alpine Club.

The maps that accompany this report have been compiled by the American Geographical Society's Cartographic Department from the best available sources. They are designed to show the geographical distribution of the glaciers and not their morphological characteristics. For more detailed information readers should consult the larger-scale maps listed in the references.

Full information on the various source materials is given in the "References Cited" section immediately following the text of each chapter. When photographs or maps appearing in one of these sources are noted in the "Photographic Sources" or "Map Sources," citation in those sections is only by author and date of publication; the rest of the information should be obtained by referring back to that author in the "References Cited" section.

Although sources and references have been carefully checked, in any compilation of this kind there are likely to be some errors, ommissions, or erroneous interpretations. When detected, these should be brought to the attention of the Society's Department of Exploration and Field Research so that suitable corrections may be made in any future editions. Additional

information on glaciers of the Southern Hemisphere and suggestions of any nature in regard to this report will also be welcomed.

The assembly of this report has been made possible through a contract with the Environmental Sciences Division of the Army Research Office, Arlington, Virginia. Administration of the project was later transferred to the U. S. Army Natick Laboratories in Natick, Massachusetts, where the report and maps were prepared for publication and printed. Grateful appreciation is extended to these agencies for making this effort possible, and to the individuals involved for their courteous and helpful cooperation.

Many of the Society's personnel have taken part in this project. Assisting Dr. Mercer in the early stages was Marshalyn K. London and in the later stages, Fern Aitchison. Editorial help was provided by Adrienne B. Conybeare. Organization of the manuscript, general supervision, and editing were carried out by Martha B. Utley; typing and proofreading, by Eda L. Sánchez, Miss Aitchison, and Georgia B. Bergnes. The layout of the maps in the Atlas was originally planned by William B. Briesemeister and Douglas V. Waugh. The cartography was carried out by the latter and, under his supervision, by the following members of the Society's cartographic staff: Peter J. Fust, Thomas Kalan, Chih Chwen Pinther, Miklos Pinther, Luba Prokop, Lidia Romash, Norman Swanston, and José G. Uzcátegui. The Society's warm thanks and appreciation are extended to all these individuals for their part in this cooperative effort.

William O. Field
Project Officer
American Geographical Society

GLACIERS OF ECUADOR

The Andes of Ecuador consist of two parallel ranges, the Cordillera Occidental and the Cordillera Oriental, with a high plateau between. Most of the information about the glaciers was obtained between 1870 and 1904 by the German investigators Reiss, Stübel, Wolf, and Meyer and the English climber, Whymper. In the last sixty years the area has attracted few climbers or scientific observers of the glaciers.

A number of careful paintings and drawings of the mountains were made during Reiss' and Stübel's expedition in 1872-74, and were deposited in Das Museum für Völkerund Länderkunde zu Leipzig (the Grassi Museum). Reiss and Stübel (1886) reproduced monochrome line drawing copies of some of these with explanatory text and later Stübel (1897) published an explanatory text of all the illustrations deposited in Leipzig. Some of these illustrations have been reproduced in monochrome by Meyer (1907 and 1938).

Whymper visited the area in 1880 and climbed many of the ice-covered peaks. His observations are contained in his book (Whymper, 1892) which also has engravings made from photographs.

Meyer carried out geographical studies of the snow-covered peaks in 1903 and 1904. His book (Meyer, 1907) is still the main source of information on the glaciers of Ecuador. It contains many photographs and other illustrations and was translated into Spanish in 1938. The illustrations in the Spanish edition have suffered in reproduction and there is no index. No English translation has been made, but an accompanying Portfolio of Plates with explanatory text has been published in English as well as in German (Meyer, 1908). The forty-three plates are photographs and excellent color reproductions of careful paintings of the mountains and glaciers. More recent sources are scanty and entirely descriptive.

The altitude of the snowline depends largely upon exposure to the easterly winds that bring moisture from the humid Amazon basin, and is thus lower in the Cordillera Oriental than in the Cordillera Occidental, and on the eastern side of a mountain than on the western side (Meyer, 1938, p. 486). In the 1870's the snowline was at about 4480 m in the east and 4660 m in the west. During the rainy months of March to May, snow may lie down to 3500 m (Meyer, 1938, pp. 485-486). Some mountains are active volcanoes, some were recently active, and other have been long extinct. A few are of nonvolcanic origin. On the undissected peaks many short ice tongues extend below the firn fields but on the older dissected mountains true valley glaciers occur (Meyer, 1938, p. 505). Nieve penitente is widespread, and Meyer (1938, p. 488) believes that another result of the intense insolation is to turn the snow into ice-cemented firn on the surface. The sunniest months are June through August and the annual layering

is clearly visible in crevasse walls (Meyer, 1938, pp. 485 and 488). At the beginning of the century recent recession was evident everywhere (Meyer, 1904, p. 155; 1938, pp. 507 and 518).

The number of mountains that rise above the snowline is uncertain because of the lack of observations. Wolf (1892, p. 405) listed sixteen and Whymper (1892, p. 347) listed two others that Wolf had not mentioned: the eighteen summits listed below may therefore have supported permanent snow at the end of the nineteenth century. Subsequent rise of the snowline has probably reduced this total.

Cordillera Occidental (from north to south)

Volcán Chiles, 4748 m

Nevado Cotacachi, 4937 m

Cerro Pichincha, 4701 m

Cerro Corazón, 4791 m

Cerro Iliniza, 5306 m

Cerro Carihuairazo, 5028 m

Chimborazo, 6272 m

Cordillera Oriental (from north to south)

Volcán Cayambe, 5796 m

Cerro Sara-urcu, 4676 m

Cerro Antisana, 5704 m

Cerro Sincholagua, 4901 m

Cerro Rumiñahui, 4719 m

Volcán Cotopaxi, 5896 m

Cerro Quilindaña, 4877 m

Cerro Hermoso, 4638 m

Volcán Tungurahua, 5033 m

Cerro Altar, 5321 m

Volcán Sangay, 5320 m

Most accounts of the ascents of the higher peaks contain descriptions of storms. Of the seventeen days spent between 4300 m and 5200 m on Chimborazo, Whymper (1892, p. 84) wrote:

> During the whole of this time, there was not one really fine day. As a rule, the weather at daybreak on Chimborazo was reasonable good at out level, and the two summits were cloudless, or nearly so. Clouds at that time, however, always existed beneath us, commencing at about 13-14,000 feet [4000 to 4300 m], . . . By 8 a.m., or thereabouts, clouds commenced to form over the eastern side of the mountain; and, gradually extending upwards, generally shut out the summits by 10 a.m. There were thunderstorms on the south side of Chimborazo on every day from Dec. 28 to Jan. 12, inclusive, and some were extremely violent. These seldom occurred before midday. Snow fell around us every day, on an average, to the extent perhaps of three inches per day.

The mountains such as Sangay that overlook the Amazon lowlands usually protrude above the cloud layer that produces almost constant rainfall lower down. Precipitation at high levels is more spasmodic and is usually associated with thunderstorm development.

Cordillera Occidental

Volcán Chiles, 4748 m

Chiles is mentioned as being permanently snow-covered by Wolf (1892, p. 405) and Reiss and Stübel (1886, p. 83). No further information is available.

Nevado Cotacachi, 4937 m

The summit of Cotacachi consists of two peaks, the higher of which is steep and nearly snow-free. A glacier occupies the depression between and may conceal a crater (Whymper, 1892, p. 264).

According to Stübel (1897, p. 89) who gave the mountain an elevation 29 m higher than recent figures, the snowline on the eastern side was at about 4700 m and on the southwest side at 4620 m. The glacier tongue on the east terminated at about 4540 m, the tongue on the south at 4500 m, and Tiucungo Glacier at 4600 m.

Cerro Pichincha, 4710 m

The top of Pichincha barely reached the snowline in 1880: numerous snowbeds lay in hollows on 22 March but were "quite trifling in extent" (Whymper, 1892, pp. 213 and 247).

Cerro Corazón, 4791 m

Corazón has a flat summit surrounded by precipitous cliffs. Whymper (1892, p. 110) found the summit and the eastern side snow-free, but much snow and possibly a glacier lay on the west side. According to Stübel (1897, p. 54) the snowline on the north side was about 120 m below the summit. Meyer (1907, p. 289; 1938, p. 332) reported only a small amount of permanent snow in favorable situations in 1904.

Cerro Iliniza, 5306 m

In 1872 the snowline on Iliniza was about 4650 m on the west and 4770 on the northeast (Reiss, 1873, p. 17; Stübel, 1897, p. 63); a west-facing glacier tongue ended at about 4480 m. The mountain has two sharp ice-covered summits and at the time of Whymper's attempted ascent in 1880 the higher summit was capped by a cornice overhanging all around. He found this type of snow formation only in the High Andes (Whymper, 1892, p. 133). Two glaciers originated in the firn field on the upper part of the southern ridge; the western one was "prodigiously steep" with tremendous seracs. The other glacier covered almost the entire eastern face of the mountain and was somewhat less steep. Part way along the ridge a vertical wall of ice about 30 m high blocked further progress. The mountain was almost perpetually shrouded in cloud and Whymper (1892, p. 134) experienced "thunderstorms, snow and hailstorms, sleet, drizzle and drenching showers, and scarcely saw the sun at all."

Meyer (1938, pp. 324-326) described the glacier between the two peaks as broad and crevassed in 1904. One glacier lay on the east side of the northern peak, and on the north-northeast and north were two deep cirques into which short ice tongues descended from the firn fields above. The terminus of the western glacier had receded about 120 m vertically since Stübel's visit in 1872 and pronounced recession of all the glaciers was general as shown by the recently abandoned moraines.

Cerro Carihuairazo, 5028 m

Carihuairazo is part of the same massif as Chimborazo, from which it is separated by a high pass. It is an extinct volcano with a crater breached in the east-northeast. Whymper (1892, pp. 315-316) climbed the mountain from the southwest by a badly crevassed glacier. The summit was "a snow cone too small to stand upon, with a little patch of rock peeping

out a short distance down upon the north side." Meyer (1907, p. 361; 1938, p. 413) counted eight glaciers on the interior walls, coalescing on the crater floor into a single ice stream that vanished farther down beneath great heaps of debris. The outer face of the crater was ice-covered also, the largest glaciers flowing to the south and southwest. Recent retreat of the ice tongues was evident in 1904 (Meyer, 1908, Pl. 17a). Stübel (1897, p. 203), taking the height of the mountain as 5106 m, gave the snowline as 4675 m on the south side and 4500 m on the north.

Chimborazo, 6272 m

Chimborazo is an extinct volcano that has been considerably dissected. The three-kilometer-long summit area of low or moderate relief has five distinct peaks (Meyer, 1938, p. 92) and is surrounded by steep slopes or precipices.

Whymper was first to climb the mountain, reaching the summit from the southwest in January 1880. After having had to cut steps in the hard snow of upper Thielmann Glacier, he came suddenly to exceedingly soft and deep snow on the summit plateau. A twelve-foot pole failed to reach bottom and "the only possible way of proceeding was to flog every yard of it down, and then to crawl over it on all fours; and, even then, one or another was frequently submerged, and almost disappeared" (Whymper, 1892, p. 68). The snow was reasonably firm on the steeper slopes of the peaks rising above the plateau. When he climbed the mountain again in early July by the upper Stübel Glacier, the snow was still deep and soft on the summit plateau (Whymper, 1892, p. 325). Half a century later, Moore (1930a, p. 102) found the same abrupt transition from the hard snow of the upper Stübel Glacier to deep, soft snow, in which they had to trample a trench.

Whymper (1892, p. 72) and Meyer (1938, p. 131) noted that many glaciers on the southern side of the mountain were fed by ice avalanches from the summit and were debris-covered in their lower parts. The largest glaciers--Abraspungo, 3 km long, Hans Meyer, and Reschreiter--are on the northeast side of the mountain: all were receding from fresh terminal moraines in 1904 when Hans Meyer Glacier terminated at 4400 m (Meyer, 1938, p. 448).

On the northwest side of the mountain, steep, broken glaciers flowed into valleys separated by sharp ridges (Meyer, 1938, p. 121). In the upper Stübel Glacier, Meyer (1938, p. 154) met huge crevasses up to 40 m wide and ice pinnacles 60 m high. The lower parts of the glaciers were completely debris-covered so that no glacier fronts were visible (Meyer, 1938, p. 125). The surface of lower Reiss Glacier was stepped, each step being debris-covered and each riser bare and sharply defined (Meyer, 1938, p. 163).

In 1904 a belt of bare, recently abandoned moraines girdled the mountain at an altitude of 4000 m to 5200 m (Meyer, 1938, p. 92). Meyer (1938, pp. 92, 127, and 160) was impressed by the amount of debris that the glaciers had transported, especially on the south side where the moraines were up to 250 m high. Comparisons of photographs showed great recession of all the glaciers between the 1870's or 1880's and 1904, and also a considerable shrinkage of Reiss Glacier in the single year between 1903 and 1904 (Meyer, 1938, p. 164).

Cordillera Oriental

Volcán Cayambe, 5796 m

Cayambe, situated almost exactly on the equator, is precipitous on the eastern side, steep on the south, and less steep on the west (Whymper, 1892, p. 228). The three summit domes are completely ice-covered; the central dome is highest. The only exposed rock on the western side in 1880 was a small cliff about 250 m below the northern summit (Whymper, 1892, p. 231).

During the ascent, Whymper passed a crevassed area at the head of Espinosa Glacier and came to an extensive snow plain. The summit ridge rose above this plain, surrounded on all sides by huge crevasses. Glaciers flowed from the summit "in a manner that is seldom seen on mountain tops." On the southwest side a debris-free glacier several miles long was "one of the finest we found in Ecuador." Two small stranded lateral moraines on the west side pointed to recent shrinkage (Whymper, 1892, p. 232).

According to Stübel (1897, p. 108), whose altitude of Cayambe is 70 m higher than that accepted today, the snowline on the northeast side was at 4400 m and on the northwest side at 4670 m. On the eastern side Muyurcu Glacier ended at 4300 m and on the northeast side Yancureal Glacier at 4130 m.

Cerro Sara-urcu, 4676 m

Sara-urcu is not of volcanic origin: the summit is a bare ridge of gneiss (Whymper, 1892, p. 249). It is the lowest of all the snow peaks of Ecuador, and is lower than several that barely reach the snowline. The mountain overlooks the Amazon lowlands, and the resultant cloudiness and high precipitation probably account for the low snowline. The summit is surrounded on all sides by glaciers, which are small on the south but larger on the west and northeast. Bad visibility prevented Whymper (1892, p. 251) from being able to describe the glaciers more fully.

Cerro Antisana, 5704 m

The summit of Antisana is the rim of a large caldera 1800 m across and open to the southeast. Tumbled masses of ice descend the 1000-meter high caldera walls and unite into a single glacier (Meyer, 1938, pp. 269 and 285), which terminated at 4216 m in 1872 (Reiss and Stübel, 1886, p. 19).

The eastern side of the mountain is considerably dissected and has several valley glaciers. The better-known western side is much less dissected and the ice tongues are not true valley glaciers (Meyer, 1938, p. 384).

Both Whymper in 1880 and Meyer in 1904 climbed Antisana by the largest ice tongue on the western side, which Meyer called simply West Glacier. Near the terminus Whymper found large and very long crevasses. At his first attempt he was stopped high up on the mountain by a "prodigious schrund" at least 20 m wide and 60 m deep. At his next attempt he found many similar crevasses, some of them 1000 m long, but managed to reach the summit--which he found to be a level plain of snow (Whymper, 1892, pp. 190-195).

Meyer noted the steep, often vertical ice cliffs at the margin of West Glacier, and the chaos of seracs at the terminus. There was almost no surface moraine, but large quantities of debris were being dumped at the margins, presumably from within and below the glacier (Meyer, 1938, p. 386).

In front of West Glacier at 4580 m were four concentric moraine ridges of recent origin and older moraines beyond (Meyer, 1938, p. 389).

Cerro Sincholagua 4901 m

The height of Sincholagua was calculated at 4988 m in 1874 (Reiss and Stübel, 1886, p. 72) and at 4901 m at the beginning of the twentieth century by French army surveyors (Perrier, 1928, map p. 366). On the American Geographical Society 1:1,000,000 map it is given as 4525 m; this must be incorrect, for Rumiñahui (4719 m) nearby barely reaches the snowline and Sara-urcu, the lowest glaciated peak overlooking the Amazon lowlands, is 150 m higher. The mountain was climbed by Whymper in 1880. He found precipitous crags surmounted by ice and snow on the east, south, and west sides and on the west side a hanging glacier crept part way down the almost vertical cliffs. A snow ridge led to the bedrock summit peak (Whymper, 1892, pp. 160-162). The lowest snowbeds lay 300 m below the summit (Whymper, 1892, p. 347). In 1874 Stübel (1897, p. 149) had estimated the snowline at 400 m below the summit.

Cerro Rumiñahui, 4719 m

Rumiñahui is a large and prominent mountain (Whymper, 1892, p. 158) whose summit is a caldera open to the west (Stübel, 1897, p. 165; Meyer, 1907, p. 227; Meyer, 1938, p. 263). Stübel made no mention of permanent snow on the mountain in 1874, but Whymper (1892, p. 347) reported a small amount of permanent snow on the east side in 1880 but none on the west. In 1904 the mountain had no permanent snow according to Meyer (1907, pp. 227 and 287; pp. 263 and 330).

Volcán Cotopaxi, 5898 m

Cotopaxi is the highest active volcano in the world, and the glaciers on it are from time to time affected by the activity. In 1877 an eruption caused great floods which carried blocks of glacier ice a distance of "8-10 leagues," and when Whymper climbed the mountain the glaciers were so ash-covered that it was impossible to tell where they began or ended (Whymper, 1892, pp. 127 and 146). In 1904, however, the surface was ash-free and Meyer was able to see the distribution of ice and snow. The ice tongues from the common névé were very short except on the east where they reached 1.5 km in length (Meyer, 1938, p. 290). Crevasses were rare low down but increased as the slope steepened higher up; exposures in crevasse walls showed no ash layers to a depth of ten to fifteen meters (Meyer, 1938, p. 274). Overhanging accumulations of ice and firn lay on the crater rim and the summit was a pyramid of firn on the north side, 65 m above the crater edge. Within 150 m of the crater the surface was of round plates of firn up to a meter across, caused by the steam from the crater (Meyer, 1938, p. 284).

A recent aerial photograph taken about 1949 (Lewis, 1950, pp. 124-125) shows the southwest side. The summit pyramid noted by Meyer on the north side of the crater is visible and considerable amounts of snow or ice lie on the inner wall of the crater. Crevassing is very heavy on the south flank of the mountain.

Cerro Quilindaña, 4877 m

The upper 900 m of Quilindaña is a sharp Matterhorn peak. In 1904 the cirque on the northeast side contained a small glacier and many small ice bodies clung to the rock face around the summit. The cirque on the west side contained permanent snow but no ice (Meyer, 1938, pp. 31, 314, and 315). Although the peak was surrounded by abandoned moraines, none were being formed by the existing glaciers (Meyer, 1908, Pl. 32). The ice tongue at the head of the Toruno River valley on the north side terminated at 4470 m in 1874, according to Stübel (1897, p. 145), who over-estimated the height of the mountain by 40 m.

Cerro Hermoso, 4638 m

Cerro Hermoso, the highest mountain in the Llanganati group, is not of volcanic origin and the upper parts consist of nearly horizontal sedimentary rocks (Wolf, 1892, p. 74). In 1857 Spruce (1861, p. 168) noted that only one peak in the group carried permanent snow although many others were rarely snow-free. According to Wolf (1892, p. 73), Reiss was the only scientific observer to have visited the area; he noted a large glacier descending the western side of the mountain and merging with the masses of snow that lay at the base. No later observations are known.

Volcán Tungurahua, 5033 m

Tungurahua is an active volcanic cone. In 1904 the summit was covered by a flat glacier over 100 m thick, with ice cliffs round the crater. The crater was eccentrically situated, and the glacier was widest in the east and southwest. Permanent snow extended far down the slopes (Meyer, 1938, p. 412). Stubel (1897, p. 266) estimated the snowline on the north and west sides to be at about 4600 m and on the south side about 4270 m.

In 1925 Dyott (1926, p. 86; 1929, p. 68) found the summit glacier smothered under layers of cinder. Hundreds of fumaroles were surrounded by ice hummocks. The eastern rim of the crater was overhung by huge blocks of ice, so heavily encrusted with cinders that they resembled solid rocks (Dyott, 1926, p. 89). Ash and cinders also covered the snow on the eastern slope, but "In some places glaciers sparkled forth . . . like jewels about the dusky throat of some Abyssinian beauty." The southeastern slopes were the least steep and carried the most ice, which formed cliffs of considerable height in many places (Dyott, 1929, p. 92).

Within a year of Dyott's visit Tungurahua, seen from the slopes of Chimborazo (Moore, 1930a, p. 104), appeared to be nearly snow-free. In the light of Dyott's observation, however, the snow may have been hidden by ash cover.

Cerro Altar, 5321 m

Altar is an extinct volcano. The summit is a horseshoe-shaped ridge, the rim of a huge caldera open to the west (Whymper, 1892, p. 305). The caldera contains Pasuasu Glacier, 2.5 km by 1 km, the second largest in Ecuador and exceeded only by one on Chimborazo (Meyer, 1938, p. 506). In 1872 it had shrunk back from a massive crescentic double end moraine at the foot of the cliff and terminated at the base of a steep rock face (about 4030 m, according to Stübel [1897, p. 239]), who gave the height of Altar as 5405 m. Much of the glacier at the base of the cliff was reconstituted from ice avalanching down the rock face. In 1880 Whymper (1892, p. 307) found the glacier in much the same condition.

By 1904 no ice reached the foot of the cliffs, and recession and degeneration of the glacier was evident everywhere (Meyer, 1906, p. 142; 1938, pp. 204 and 213). Icefalls down the 1000-m caldera walls formed six ice streams separated by ridges that had been ice-covered in 1872. The ice streams united and flowed out of the caldera as one glacier. Near its terminus the glacier was very broken and thickly covered with debris and had shrunk about 30 m vertically in 30 years (Meyer, 1938, pp. 210-212). The climatic snowline in 1903 was about 4750 m (Meyer, 1906, p. 148).

The outer slopes of the caldera also have glaciers. In 1903 on the northeast side of the northern peak an ice-fall descended and split into two glaciers, one flowing northeast and the other southeast (Meyer, 1938, p. 222).

Volcán Sangay 5320 m

Sangay is an almost continuously active volcano, detached from and rather to the east of the main Cordillera (Moore, 1950, p. 218). It is very difficult of access and was first reached by Dyott in 1925. He was unable to reach the summit in two attempts for the snow became softer and deeper as he went higher. Round the crater itself the rock was bare (Dyott, 1926, pp. 59 and 68; 1929, pp. 58 and 67).

In 1929 the mountain was climbed by Moore who, after 18 days of constant rain at lower levels, emerged through the cloud layer into sunshine (Moore, 1930b, p. 229). In contrast to Dyott's experiences, hard snow and glare ice were encountered above 5000 m and steps had to be cut (Moore, 1950, pp. 275-277). The ice on the south side of the mountain was badly crevassed. A new cone several hundred feet high had recently formed and the entire rim of the main crater was sheeted with ice. Ice patches were seen far down in the crater, and many ice hummocks were near the summit, perhaps formed by fumaroles (Moore, 1950, pp. 276, 277, and 286).

In 1946 an attempt to climb the mountain had to be abandoned because of the volcanic activity. An aerial photograph shows much of the summit area black with ash, with streaks of ash or lava descending far down the mountainside (Lewis, 1950, pp. 119 and 138).

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Photographs and Other Illustrations

CORDILLERA OCCIDENTAL

Nevado Cotacachi

Whymper (1892)	
P. 263.	E side, engraving from photograph.

Cerro Pichincha

Blomberg (1952)	
P. 174.	

Cerro Corazón

Meyer (1907)	
Fig. 67.	W side, 1872 drawing.

Cerro Iliniza

Reiss and Stübel (1886)	
Fig. 51.	SE side, line drawing from 1872 painting.
Fig. 53.	W side, line drawing from 1872 painting.
Meyer (1907)	
Fig. 65.	W side, monochrome reproduction of 1872 painting.

Cerro Carihuairazo

Reiss and Stübel (1886)	
P. 21.	S side, line drawing from 1872 drawing.
Meyer (1907)	
Fig. 32.	NE side, 1872 drawing.
Fig. 33.	E side, 1904 drawing.
________ (1908)	
Pl. 16.	NE side, 1904 painting.
Pl. 17a.	W side, 1904.

Chimborazo

Reiss and Stübel (1886)	
P. 21.	S side, distant, line drawing from 1872 painting.
P. 25.	SW side, line drawing from 1872 painting.
Whymper (1892) [Engravings from	photographs taken in 1880.]
P. 24.	SW side.
P. 64.	SW side, summit ice cliffs, from 5300 m.
P. 76.	SW side, summit ice cliffs, from 5650 m.
P. 377.	S side, summit ice cliffs.
P. 320.	NNW side, summit ice cliffs.
Meyer (1904)	
Fig. 1.	Nieve penitente, 1904.
Fig. 4.	NW side, 1904.
_______ (1907)	
Figs. 16, 21, 23, 25, 26, 29, 94, and 95.	Chimborazo from various directions in 1904.
Fig. 19	SE side, monochrome reproduction of 1872 painting.
Figs. 28 and 92.	Ice wall on W summit, 1904.
Fig. 91.	Part of Stubel Glacier, 1904.
Figs. 102 and 103.	Nieve penitente, 1904.
_______ (1908)	
Pls. 5b, 8a, 12a, 12b, 15a, and 15b.	1904 photographs.
Pls. 4, 6, 10, 11, 13, and 14.	1904 paintings.
Blomberg (1952)	
P. 140	

CORDILLERA ORIENTAL

Volcán Cayambe

Whymper (1892)	
P. 233.	W side, 1880 engraving.

Meyer (1907) Fig. 113.	NE side, 1874 drawing.
______ (1908) Pl. 39b.	NNW side, 1904.
Stabler (1917) P. 252.	Terminal area of a glacier.
Meyer (1938) Fig. 87.	NE side, 1874 drawing [same as Meyer, 1907].
Blomberg (1952) P. 149.	N [?] side.

Cerro Sara-urcu

Whymper (1892) P. 247.	Engraving from Corredor Machai.

Cerro Antisana

Reiss and Stübel (1886) P. 8.	W side, line drawing of 1872 painting.
Whymper (1892) P. 190.	SW side, engraving.
Wolf (1892) Pl. 4, p. 88.	SW side, drawing.
Meyer (1907) [All of Meyer's illustrations were made in 1904.]	
Fig. 77.	SSW side.
Fig. 79.	ESE side, 1872 painting.
Fig. 80.	Upper icefield from 5000 m.
Fig. 81.	West Glacier terminus.
Figs. 82-84.	Margins of West Glacier.
Figs. 85-86.	Ice features on W side of mountain.
______ (1908) [All of Meyer's illustrations were made in 1904.]	
Pls. 35b and 36.	SW side, painting.
Pls. 37a and 37b.	Lateral ice cliffs of West Glacier.
Pl. 38.	West Glacier and mountain behind, painting.
______ (1938) [All of Meyer's illustrations were made in 1904.]	
Fig. 51.	SSW side [same as Meyer, 1907, Fig. 77].

Fig. 54.	Upper icefield from 5000 m [same as Meyer, 1907, Fig. 80].
Fig. 55.	West Glacier terminus [same as Meyer 1907, Fig. 81].
Figs. 56-58.	Margins of West Glacier [same as Meyer, 1907, Figs. 82-84].
Figs. 59-60.	Ice features on W side of mountain [same as Meyer, 1907, Figs. 85-86].

Cerro Sincholagua

Reiss and Stübel (1886)	
P. 72.	W side, 1884 line drawing from painting.
Whymper (1892)	
P. 161.	WNW side, 1880, engraving from photograph.

Cerro Rumiñahui

Reiss and Stübel (1886)	
Fig. 49.	E side, line drawing from 1874 painting.
Meyer (1907)	
Fig. 66.	SSE side from W side of Cotopaxi, 1904.
_______ (1938)	
Fig. 45.	SSE side from W side of Cotopaxi, 1904 [same as Meyer, 1907, Fig. 66].

Volcán Cotopaxi

Reiss and Stübel (1886)	
Figs. 42-44.	W. E. and NW sides, 1872 sketches.
Wolf (1892)	
Pl. 3, p. 80.	W side, 1874 painting.
Meyer (1904)	
Fig. 2.	Ice formation on crater rim.
_______ (1907)	
Fig. 48.	Painting of N side, 1874.
Fig. 50.	W side, 1904.
Fig. 57.	S side, inner rim of crater, 1904.
Fig. 58.	S side, 1904.

______ (1908) Pl. 22a.	N side, 1904.
______ (1938) Fig. 62.	N side, 1904 [same as Meyer, 1907, Fig. 88].
Dyott (1929) Pp. 66 and 78.	Summit area.

<u>Cerro Altar</u>

Reiss and Stübel (1886) P. 43.	Pasuasu Glacier and caldera, line drawing from 1872 painting.
P. 45.	SE side, line drawing from 1872 painting.
Meyer (1904) Fig. 3.	Pasuasu Glacier.
______ (1906) P. 140.	Pasuasu Glacier, 1904.
P. 141.	Pasuasu Glacier and caldera, monochrome reproduction of 1872 painting.
______ (1907) Fig. 38	Pasuasu Glacier, 1904 [cf Reiss and Stübel, 1886, p. 43].
Fig. 40	Pasuasu Glacier, 1904, detail of terminal area.
Fig. 41	Panorama of Pasuasu Glacier, monochrome copy of painting.
Fig. 100.	Ice cover on a high point of Altar, copy of a drawing.
______ (1908) Pl. 17b.	Pasuasu Glacier, 1904.
Pls. 18a and 18b.	W side, 1873 and 1903, paintings [Pl. 18b is same as Meyer, 1907, Fig. 38, but in color].
Pl. 19.	Panorama of Pasuasu Glacier, [same as Meyer, 1907, Fig. 41, but in color].
______ (1938) Fig. 22.	Pasuasu Glacier, 1904, detail of terminal area [same as Meyer, 1907, Fig. 40].

Fig. 23.	Ice cover on a high point of Altar, copy of a drawing [same as Meyer, 1907, Fig. 10].
Fig. 43.	Pasuasu Glacier, 1904 [same as Meyer, 1907, Fig. 38].

Volcán Sangay

Dyott (1926)	
P. 50.	
_______ (1929)	
P. 57.	Smooth outline of ice cover.
Pp. 58 and 59.	Lower edge of ice cover.
P. 60.	Entire mountain.
Moore (1930a)	
P. 104.	Mountain, much obscured.
_______ (1950)	
P. 217.	Mountain, partly obscured.
P. 276.	Ice round the crater.
P. 277.	On the summit.
Lewis (1950)	
P. 119.	SW side, summit area, aerial view.
Blomberg (1952)	
P. 223.	Temporary snowline below the glaciers.

Note: According to Pan American Union (1964), aerial photographs of some of the ice-covered mountains were taken in 1955-56 and in 1961-64; the earlier photographs are held by the Instituto Geográfico Militar in Quito, and the later ones by the U. S. Air Force.

Map Sources

American Geographical Society, New York, Hispanic America, 1:1,000,000.

N.A-18	Cali, 1958 [shows Volcán Cayambe].
S.A-18	Iquitos, 1962 [shows Cerro Sara-urcu].
N.A-17	Río Mira-Islas Galápagos, 1948 [shows Cerro Cotacachi].
S.A-17	Quito, 1948 [all others].

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28-II	Cotacachi (Nevado), 1938.
55-XVIII	Corazón [undated preliminary].
55-XXV	Rumiñahui [undated preliminary].
56-XVI	Sincholahua [undated preliminary].
71-V	Ilitio [undated preliminary; shows SW part of Volcán Cotopaxi].

Stübel (1897)
Accompanying map. Das Vulkangebiet von Ecuador, 1:250,000.

Meyer (1907) [Both maps were published by the Bibliographishes Institut, Leipzig.]

P. 69.	Spezialkarte des Chimborazo, 1:60,000. [Also shows the S side of Carihuairazo.]
P. 155.	Die Vulkanberge von Mittelecuador, 1:200,000. [Shows Altar, Antisana, Cotopaxi, Quilindaña, Rumiñahui, and Sincholagua.]

_______ (1938)

P. 88.	[Same as Meyer, 1907, p. 69.]
P. 192.	[Same as Meyer, 1907, p. 155.]

Note: According to Pan American Union (1964), a new series of maps on a scale of 1:50,000 was started in 1961; some of the completed maps include the ice-covered mountains.

______ (1938)	
Fig. 28.	Painting of N side, 1874 [same as Meyer, 1904, Fig. 48].
Fig. 35.	W side, 1904 [same as Meyer, 1907, Fig. 50].
Fig. 36.	S side, inner rim of crater, 1904 [same as Meyer, 1907, Fig. 57].
Fig. 37.	S side, 1904 [same as Meyer, 1907, Fig. 58].
Moore (1941)	
P. 728.	Distant view.
Sorensen (1948/49)	
Pp. 4 and 8.	SW side.
P. 9.	Crevasses.
Lewis (1950)	
Pp. 124-125.	SW side, aerial view.
Blomberg (1952)	
P. 140.	W side.
P. 141.	Snowfields.
<u>Cerro Quilindaña</u>	
Meyer (1907)	
Fig. 61.	W side, 1874 painting.
Fig. 63.	N side, 1904.
______ (1908)	
Pl. 32.	1904 painting.
______ (1938)	
Fig. 40.	W side, 1874 painting [same as Meyer, 1907, Fig. 61].
Fig. 42.	N side, 1904 [same as Meyer, 1907, Fig. 63].
<u>Volcán Tungurahua</u>	
Reiss and Stübel (1886)	
Figs. 25-31.	Line drawings from paintings of the 1870's.
Meyer (1907)	
Fig. 88.	N side, 1904.

GLACIERS OF PERU

The Peruvian Andes contain the most extensive tropical glaciers in the world, many of them in virtually unexplored and unmapped mountain ranges. The best-known and best-mapped are in the Cordillera Blanca and the Cordillera Huayhuash in the northern part of the country. Most are steep alpine glaciers in rugged mountain country, but glaciers also occur on a few volcanic cones and one small icefield lies on nearly flat country. Recession, sometimes spectacular, has prevailed in recent decades, and in the Cordillera Blanca the break-out of the resultant moraine-dammed lakes has taken thousands of lives. Deglaciation may also have been responsible for a great avalanche disaster in 1962.

Precipitation is derived from the Amazon Basin, and the snowline rises to the south and west from about 4800 m to over 6000 m, being highest in the vicinity of Arequipa.

Scientific study of the glaciers on a small but increasing scale has been carried out by the Instituto Geológico del Perú.

There is little consistency in the literature and cartographic sources on the generic term for mountain names. The same mountain may appear as "Nevado," "Monte," "Cerro," "Pico," or--especially in mountaineering literature--without any denomination at all. Here, the generic names on the American Geographical Society's 1:1,000,000 maps and on the large-scale topographical maps of the Cordillera Blanca and Cordillera Huayhuash made by the Alpenverein, Innsbrück, are used, but only the first time a peak is mentioned. No generic name at all is given to peaks that do not appear on these maps.

Glaciers to the North of the Cordillera Blanca

At the end of the nineteenth century Cerro Huailillas (7°45'S, 78°03'W) was the most northerly Peruvian mountain with permanent snow (Broggi, 1943, p. 65). In 1909, however, Sievers (1914, p. 208) learned that it had been snow-free since 1905. The next most northerly was "Nevado de Pelagatos," said to be at 7°59'S and 77°26'W. [This may be Cerro Ventanilla, 7°56'S, 77°23'W, or Cerro Pelagatos, 8°05'S, 77°15'W, on the American Geographical Society 1:1,000,000 map.] In 1918 ice extended 200 m below the summit, but probably in 1927 and more certainly in 1941 the mountain was ice-free (Broggi, 1943, p. 65).

In recent years the most northerly ice-covered mountain has been the southern peak of Pelagatos Meridional (4928 m), 8°12'S, 77°46'W [not to be confused with Cerro Pelagatos, above]. In 1942 permanent snow extended about 250 m below the summit (Broggi, 1943, p. 65). About 1946 Heim (1948,

p. 128) reported one small glacier; the snowline at 4800 m was lower than to the south because of greater precipitation.

Between Pelagatos Meridional and the Cordillera Blanca is a range about 12 km long, centered at 8°26'S and 77°49'W. Sievers (1914, p. 206) referred to it as the Cordillera de Conchucos but it is not named on recent maps. On the Peruvian 1:200,000 map [Sheet 7c, Corongo] it contains the Nevados Rosko Grande, Rosko Chico, Pacra, and Kaico, the maximum elevation being 5188 m. Little information is available about the mountains; photographs taken in 1908 show a rugged range with cirque-type glaciers and some ice-covered summits (Schlagintweit, 1911, p. 89).

Cordillera Blanca

The Cordillera Blanca is about 180 km long, parallel to the coast and extending from about 8°40'S to 10°S. It forms the continental watershed. The range was surveyed by the Österreichischen Alpenvereins in the course of three expeditions in 1932, 1936, and 1939, and three maps were published (1:100,000, north part, Kinzl, 1942; 1:100,000, south part, Kinzl, 1949; 1:200,000, whole range, Kinzl and Schneider, 1950). Much scientific work was carried out and fourteen peaks over 6000 m were climbed. The results and photographs of these expeditions, brought together by Kinzl and Schneider (1950), constitute the best source of information on the area. During and since the war some glaciological observations have been made (Broggi, 1943; Oppenheim and Spann, 1946; Heim, 1948; Spann, 1949?; and Smith, 1957) and climbing expeditions have taken glacier photographs.

According to Kinzl and Schneider (1950, p. 25) the summits of the Cordillera Blanca rise about 1500 m above the snowline as in the Western Alps. The glaciers are in many respects different from those in the Alps, however. They are rarely more than 4 km long, the ablation areas are steep, thin, and short, and most are so broken that travel on them is difficult or impossible. Gigantic cornices are common on the ridges, always overhanging to the west. Everywhere they are deceptive and dangerous; Matthews and Harrah (1951, p. 29) describe a near disaster after one gave way. Hauser (1959?, p. 93) reported double paper-thin cornices of a type he had never seen before in the Alps or Himalayas.

Fluted névé is common on the highest and steepest faces below the cornices. Kinzl and Schneider (1950, p. 25) believe that it is formed by eddy currents ascending the western faces as a result of the prevailing easterly winds. Except on the south sides of the mountains the snow is usually less than 10 cm thick, probably because of solar melting and refreezing. The hot sun and cold air also result in abundant icicle formation. On the south sides of the mountains, however, snow is often deep and soft.

The Cordillera Blanca is divided by deep valleys or "quebradas" into groups of ice-covered summits. These will be described from northwest to southeast.

Nevado Champará (5749m)

The main summit of Nevado Champará is a broad, ice-covered dome of black slate lying on granodiorite (Kinzl and Schneider, 1950, p. 24). In 1909 Sievers (1914, p. 204) noted recent glacial shrinkage and the presence of nieve penitente. Photographs taken in 1936, probably of the western side of the highest point, show a flattish summit glacier ending in cliffs above a precipice. Below the precipice a steep, broken glacier ends at a small, recently-formed lake and an older lake lies beyond. (Kinzl, 1942, p. 2, Fig. 3; Kinzl and Schneider, 1950, pp. 58 and 102).

Group Between the Quebrada Quitaracsa
and the Quebrada Santa Cruz

Four peaks rise over 6000 m between the Quebrada Quitaracsa and the Quebrada Santa Cruz: Quitaraju (ca. 6100 m) and the Nevados Santa Cruz (6259 m), Alpamayo (ca. 6000 m), and Pucahirca (6050 m). Lower peaks are Taulliraju and the Nevados Milluacocha and Pilanco. All are rugged peaks with steep, broken glaciers around them. Alpamayo is a slender pyramid, almost completely covered with fluted névé, and with tremendous cornices.

Huandoy Group

The Huandoy group between the Quebrada Santa Cruz and the Quebrada Yanganuco forms a horseshoe centered on Laguna Parrón and open to the southwest, and consists of Aguja Nevada (5886 m), Artesonraju (6025 m), Pyrámide or Garcilaso (5885 m), Chacraraju (ca. 6000 m), Cerro Yanapaccha (5460 m), and Nevado Huandoy (6356 m). Photographs give much evidence for glacial recession: for instance, on the south side of Huandoy (Ortenburger, 1955, p. 26). Glaciers near the head of Laguna Parrón shrank greatly between 1932 (Kinzl and Schneider, 1950, p. 105) and 1947 (Heim, 1948, Fig. 144).

Laguna Parrón is 3 km long and 800 m broad and lies 4185 m above sea level. It is dammed by a glacier on the northwest side of Huandoy, carrying such a heavy load of debris in its lower reaches that it resembles a rock glacier (Heim, 1948, p. 162). It has shrunk considerably in its middle reaches, but lower down the debris cover has protected the ice from ablation. Heim believes that if the ice continues to melt slowly, a catastrophic draining of the lake will be avoided.

Huascarán Group

The Huascarán group, lying between the Quebrada Yanganuco and the Quebrada Ulta, consists of Nevado Chopicalqui and the four peaks of Nevado Huascarán (6768 m).

The summits of Huascarán are rounded and carry summit glaciers ending in ice cliffs above precipices on the southwest side. Below the precipices the mountainside is completely ice-covered, with short ice tongues extending below the otherwise almost horizontal ice margin. In 1962 a mass of ice fell 700 m from the western side of the Pico Norte onto the glacier below, incorporated part of the end moraine, and surged down the valley, lubricated partly by meltwater produced by the heat of friction (Arnao, 1960-61, p. 83). Tremendous destruction and loss of life resulted (McDowell, 1962).

A glacier about 5 km long flows north from Huascarán and Chopicalqui, its lower part almost entirely hidden by debris. According to Kinzl (1949, p. 12), photographs of this glacier in 1904 (Enock, 1908, p. 176) and 1932 show no appreciable change, but shrinkage was marked between 1932 and 1940.

Chopicalqui is a steep, rugged peak, with fluted névé and large cornices.

Contrahierbas Group

The Contrahierbas group lies at the head of the Quebrada Ulta, and reaches an altitude of 6036 m.

Group Between the Quebrada Ulta and the Quebrada Honda

The group between the Quebrada Ulta and the Quebrada Honda is dominated by Nevado Hualcán (6150 m) and Nevado de Copa (6188 m). It differs from the remainder of the range in having extensive firn fields at high levels (Kinzl and Schneider, 1950, p. 24).

Atlante Glacier, on the northeast side of the group, is close to a mine and more is known of its variations than of any other glacier in the Cordillera Blanca. In 1909 Sievers (1914, p. 200) was told that the firn limit on the glacier had risen about 50 m since 1895. In 1932 Kinzl (1949, p. 14) visited the glacier and learned of a small advance about 1920. The glacier has receded since, terminal recession averaging about 10 m a year from 1939 to 1948, but only 2 m a year from 1948 to 1957 (Smith, 1957).

Group between the Quebrada Honda and the Quebrada Cayesh

Between the Quebrada Honda and the Quebrada Cayesh are Tocllaraju (6037 m), Palcaraju (6110 m), and the Nevados Copap (5587 m) Ranrapalca (6162 m), Pucaranra (6147 m), Chinchey (6222 m), and Cayesh (5721 m).

The 1:100,000 map shows the summit area of Copap to be an extensive ice-covered plateau; Condormina Glacier descends from the southern side to the head of the Quebrada Honda. Pucaranra and Pacliash glaciers also flow toward the head of the Quebrada Honda from Pucaranra and Palcaraju. All three glaciers were visited in July 1957 and their fronts were surveyed for future reference. They carry much debris and have receded from fresh, nearly bare moraines. An older, vegetated moraine and a much older vestigial moraine lie beyond. Aerial photographs were taken in 1948 and 1950 and from then until 1957 Condormina and Pacliash glaciers retreated about 8 m a year (Smith, 1957). Pucaranra Glacier was photographed from almost the same point in 1939 (Kinzl and Schneider, 1950, p. 80) and 1959 (Ortenburger and Dingman, 1960, Pl. 21). Considerable recession and shrinkage of the glacier are evident, and also some decrease in the ice cover higher up the mountain.

Apart from Copap, the other mountains in this group are steep and rugged, with cornices and fluted névé above and steep broken glaciers below. Cayesh in particular is spectacularly steep.

Moraine-dammed lakes have formed in front of several receding glaciers. The lake Palcacocha on the southwest side of Pucaranna burst through its barrier in December 1941; the flood destroyed a large part of Huarás, 20 km away, killing thousands of people (Kinzl and Schneider, 1950, p. 25; McDowell, 1962, p. 870). On the southwest side of Ranrapalca the glaciers in the Quebrada Llaca ended 500 m higher in 1942 then in 1903 (Broggi, 1943, p. 67). On the southwest side of Pucaranra a glacier that calved into the lake Bayococha in 1932 (Kinzl, 1949, Pl. 9) had withdrawn away from and above the lake by 1952 (Egeler and de Booy, 1955, photo p. 180).

During the ascent of Palcaraju, snow that was "knee, hip and even chest-deep" was encountered by Ortenburger and Dingman (1960, p. 28).

Group Between the Quebrada Cayesh and Punta Yanashallash

Between the Quebrada Cayesh and Punta Yanashallash are Uruashraju (5735 m), and the Nevados San Juan (5843 m), Huantsán (6395 m), Cashan (5723 m), and Rurec (5320 m). The ice and snow formations are typical of the Cordillera Blanca. Glaciers on the south side of Uruashraju shrank appreciably between 1932 and 1936 (Kinzl, 1949, pp. 11 and 12). In 1936

a glacier on the southwest side of Rurec just reached the lake; by 1939 only avalanche ice did (Kinzl, 1949, pp. 12 and 13).

South of Punta Yanashallash

South of Punta Yanashallash are many ice-covered massifs separated by broad ice-free gaps. The summits are all below about 5700 m and except for Caullaraju and Rajutuna have not attracted the attention of climbers. They include Nevado Yanamarey (5262 m), Pucaraju (5346 m), Nevado Pongos (5711 m), Nevado Raria (5590 m), Nevado Huaiacu (5460 m), Nevado Tuco (5479 m), Caullaraju (5686 m), Rajutuna (5360 m), and Nevado Pampash (5335 m).

Glaciers East of the Cordillera Blanca

East of the Río Marañon at about 76°55'W, 8°45'S, is Cumbre de Acrotambo, with an altitude of 4220 m on the American Geographic Society 1:1,000,000 map. In 1909 Sievers (1914, p. 166) referred to it as Nevado de Acrotambo, claiming that a small amount of permanent snow lay on the northwest side and rather more on the southwest. He estimated that the mountain was less than 400 m higher than the firn limit of 4800 m.

Cordillera Huayhuash

The Cordillera Huayhuash is a small but spectacular range about 30 km long, with six peaks over 6000 m. According to Kinzl (1955b, p. 38) it is undoubtedly an independent mountain chain, separated from the Cordillera Blanca by a broad unglaciated zone.

In 1909 Sievers (1914) visited the eastern side of the range and took photographs (Kinzl, 1955b, p. 40). In 1936 Awerzger, Kinzl, and Schneider from the Osterreichischen Alpenvereins visited the range; the most important result of their work was the production of a topographical map of the main concentration of glaciers on a scale of 1:50,000. In 1946 Heim took a number of aerial photographs of the range and in 1950 Nevado Yerupaja, the highest peak (6634 m), was climbed by a Harvard University expedition. In 1954 another Osterreichischen Alpenvereins expedition visited the area. Kinzl (1955b) has written the best general description of the area from information up to and including this expedition. A further Alpenvereins expedition in 1957 was primarily concerned with mountaineering.

According to Kinzl (1955b, p. 39) the glaciers of the Cordillera Huayhuash are more like those of the Alps than are those of any other Peruvian mountain group. As in the Alps, long, narrow ice tongues flow

from flat-lying firn basins below steep rock walls. They are, however, steeper, thinner, and much more crevassed than the Alpine glaciers and cannot be used as routes of approach. Many have rock windows and reconstituted glaciers are common, the largest being Siulá Glacier on the east side of Yerupajá; it is 2 km long and entirely covered by rubble.

As in the Cordillera Blanca most precipitation comes from the east, and cornices always overhang on the western side. For reasons of topography the largest glaciers are on the western flanks, where they reach about 4 km in length, similar to the eastern Alps. Because of differing exposures to the moisture-bearing wind, the firn limit rises from about 4900 m in the northeast to 5000 m in the southeast and to 5200 m in the southwest (Kinzl, 1955b, p. 39).

In 1909 Sievers (1914, p. 177) observed that many glaciers had receded about 150 m from massive fresh moraines. In 1936 they were in much the same positions as in 1909, and Kinzl (1955b, p. 40) believes that the readvance that is known from the Cordillera Blanca and the Alps about 1920 may have affected the Cordillera Huayhuash also. Between 1936 and 1954 large glaciers did not change much, but small and medium-sized glaciers shrank noticeably, particularly the one on the northwest side of Nevado Tsacra Chico and the one entering the lake Sarapococha from the south side of Yerupajá. The glacier on the northeast side of Yerupajá that had changed little between 1909 and 1936 had begun to break up in its lower parts by 1954 (Kinzl, 1955b, p. 40; and compare Sievers, 1914, Pl. 12, and Kinzl, 1955b, Pl. 52). The 1957 Austrian expedition noted that the mountains were much more subject to avalanches than in 1954 (Klier, 1959?, p. 83).

As in the Cordillera Blanca, moraine-dammed lakes have formed as the glaciers have receded. Many grew much larger between 1936 and 1954. In 1936 Yerushcocha on the southwest side of Nevado Sarapo was a very small lake in front of a reconstituted glacier. It must have grown considerably in the next few years, for in 1941 the lake partially emptied catastrophically, causing much damage (Kinzl, 1955b, p. 41). In 1954 it was about 400 m long and the reconstituted glacier had almost disappeared.

Huagaruncho Area

East of the Cordillera Huayhuash and of the railway to Cerro de Pasco is a mountain range, the Cordillera Occidental of Arnao (1962/63), containing the ice-covered Cerro Huagaruncho (75°54'W, 10°28'S); the only other glaciers in the range are two on a mountain near Horno Mackay, about 75°52'W, 10°54'S (Harrison, 1947, p. 225; 1951, p. 12).

Huagaruncho (5730 m or 5870 m) is a highly dissected mountain; as in the Cordillera to the west, there are huge cornices along the crests,

other glaciers in the area have receded about 100 m. The recession here, according to Broggi (1943, p. 71), has been less than in areas to the west and north.

"Andes Centrales"

Northeast of Lima, the ranges north and south of the trans-Andean railway have been referred to as the "Andes Centrales." Arnao (1962/63) has divided them into the Cordillera La Viuda north of the railway and the Cordillera Central to the south. The area is notable for the spectacular glacial recession that has taken place. Near the source of the Rio Rimac, Broggi (1943, p. 73, Figs. 1-3) has estimated that the snowline was 4600 m in 1862, 4900 m in 1923, and 5100 m in 1942, his evidence being a painting by Raimondi and two photographs by himself of the glaciers in the Rimac valley.

Further rapid recession of the glaciers in the Rimac valley was evident in aerial photographs taken in 1950. All the glaciers are on the west side of the ridges because of afternoon cloudiness, and snowfall is turned to ice in a few days by melting and refreezing (Dollfuss, 1959, p. 37).

Paragte nearby had small glaciers in 1917 which had shrunk by 1923 and completely disappeared by 1942, according to photographs by Broggi (1943, Figs. 4-6). He estimated the rise in the snowline at 500 m.

Close to the railway line a glacier that existed in 1890 had virtually disappeared by 1942 (Broggi, 1943, pp. 82-83). Northwest of the lake Morococha on the north side of the railway, Hauthal (1911, p. 147) was informed that the glaciers advanced briefly but sharply in 1886-87. From then until his visit in 1908 they had been receding. In 1944 the Instituto Geológico del Perú set up a bench mark in front of Yanasinga Glacier (11°35'S, 76°10'W) near the railway line. The glacier ended in a vertical face and calved into a lake at 4838 m (Oppenheim and Spann, 1946, pp. 3 and 4).

South of the railway is the Toldorumi massif. In 1908 the western side carried more ice than the east. A depression on the south side contained a well-developed glacier whose tongue reached 1200 m below the summit (Hauthal, 1911, pp. 158 and 160). In the same general area is the Sierra de Tunshu, a fairly compact group of mountains centered at about 11°55'S and 76°W, and reaching about 5800 m. In 1939 the south side of Pachancoto (5394 m) was covered by an "exceptionally large glacier" (Jenks, 1941, p. 174). In 1946 Heim and Spann visited the area and climbed Tuyujuto (5752 m). Photographs show rugged peaks with large cornices on the crests and short ice tongues below. Heim saw signs of

considerable recent recession, and believed that if it continued at the same rate for another 50 years the glaciers would disappear (Heim, 1948, p. 94).

Sierra de Huaytapayana

An ice-covered group of mountains lie northeast of Huancayo, centered about 11°54'S, 75°05'W. It has been referred to as the "Lasontai Group" (Jenks, 1941, p. 176), the "Sierra de Huaytapayana" (Heim, 1948, p. 84), and the "Cordillera Huaytapallana" (Arnao, 1962/63). Harrison (1947), who surveyed the area in 1945, used none of these names on his map, but called the main ice-covered area "Nevada de Chuspe."

According to Harrison (1951, p. 9) ice is almost continuous for 19 km on the western side of the range; the ice has receded so that 800 m of bare moraine must be crossed on the west side before the ice is reached. The east side has much less ice because of its slight northerly aspect. Northeast of the main group small summit glaciers lie on the highest peaks, such as Condorvasha and Paragcho Grande. All showed signs of recent retreat (Harrison, 1947, pp. 223-224).

In 1946 Heim and Spann visited the area. A cement marker was placed near the terminus of the small Huaytapayana Glacier at 12°6'S, 75°10'W (Heim, 1948, p. 85; Spann, 1949?). Heim noted considerable recession from moraines that he believed were about a century old. He photographed a glacier on the southeast side of Lasontai, terminating on the edge of a moraine-dammed lake (Heim, 1948, Pl. 94); when this glacier was photographed from the air about 1932 its calving front extended halfway down the lake (Shippee, 1933, p. 120).

In 1939 the firn limit was estimated at 4900 m to 5000 m (Kinzl and others, 1941, p. 13).

Cordillera Occidental de la Costa

In the Cordillera Occidental de la Costa, glaciers are confined to a group of volcanic peaks northwest of Arequipa in a range that Arnao refers to as the Cordillera Ampato. Elsewhere the Cordilleras Chonta, Huanzo, and Chila, marked as ice-covered on many maps, in fact have no permanent snow (Arnao, 1962/63). Southeast of the Cordillera Ampato toward the Bolivian border the snowline is very high: Chachani (6087 m) carries some permanent snow but no glaciers, and Heim (1948, p. 61) estimated the firn limit at 6000 m. According to Broggi (1943, p. 81) the snow cover has not appreciably changed during the present century. Southeast of Chachani the snowbeds on El Misti (5842 m) and Pichu-Pichu (5600 m) last

fluted névé, and very broken glaciers below. Westmacott (1959?, p. 69) reached the summit and remarked on the snow, which was waist-deep at 5200 m and later "up to my neck" (Westmacott, p. 72); "None of us had met such soft snow before, lying at such a high angle" (p. 71).

In 1945 a bench mark (a cairn) was set up by "Huagoruncho" Glacier, 10°30'S, 75°50'W, for future observations (Spann, 1949?).

In October 1952 at the beginning of the accumulation season, ablation studies were made on a small glacier on the southern side of the mountain. This work was in connection with a power plant on a glacier-fed river. Ablation was found to consist largely of melting from solar radiation and amounted to between 1.0 cm and 1.5 cm of water daily, mostly before afternoon cloudiness set in. Evaporation was only about 5 percent of the melt (Howell, 1953, p. 888).

Cordillera Raura

Southeast of the Yerupajá group lies another, less spectacular range of ice-covered summits. Geographical names are confused; Jenks (1941, p. 158), Kinzl, (1955b, p. 39), and Arnao (1962/63) restrict the Cordillera de Huayhuash to the 30-km-long Yerupajá group, but on the American Geographical Society 1:1,000,000 map it extends 120 km to beyond 11°S. On Jenks' map are a Cordillera de Raura, a Raura Range, and a Cerro Raura, and his Raura Glacier is not the same as Kinzl's and both differ from Broggi's (1943, p. 69). According to Arnao (1962/63), the Cordillera Raura is a continuation of the Cordillera Huayhuash, from which it is separated only by the Laguna Viconga.

Kinzl's Raura Glacier is centered about 10°25'S, 76°48'W, and extends over at least 16 sq. km. It is a typical plateau glacier with few crevasses and little surface debris. In 1909 Sievers (1914, p. 176) noted an outlet glacier from this icefield that ended 130 m above Laguna Viconga; he thought that it had fairly recently receded from the lake. In the map from the Austrian survey of 1936 a glacier tongue is shown 203 m above the lake.

Southeast of this large plateau glacier are several ice-covered mountains with short, steep glaciers, many of which end in lakes. Sievers (1914, pp. 171-174) was in the area in 1909 and in 1927 the American Geographical Society carried out survey work. Photographs of "Raura" Glacier ending in Laguna Santa Ana that were taken in 1927 and 1943 show considerable thinning and recession of the lower glacier but no noticeable change in the ice cover higher up (Broggi, 1943, p. 69). Photographs of the margin of the glacier taken in 1921 and 1943 show recession of about 70 m;

throughout some exceptional years but usually disappear (Johnson, 1930, p. 23). In the 1820's also, according to Pentland (1835, p. 74), El Misti and Chachani were at times devoid of snow.

Glaciers in the Cordillera Ampato lie on the Nevados Sara-Sara, Solimana, Coropuna, and Ampato.

Sara-Sara (ca. 5530 m; 15°19'S, 73°25'W), west of Solimana, was photographed about 1912 by Bingham (1922, p. 78).

Solimana (6117 m) is a rugged mountain with many precipices near the summit. Ghiglione (1953?a, p. 174; 1954, p. 139), who ascended the north summit, crossed a glacier with a surface of pinnacle ice and ascended a difficult fifty-degree slope, part ice and part snow.

Coropuna (6425 m) is an extinct volcano. Bingham (1922, p. 36) climbed the mountain in 1911 by a glacier with a network of narrow crevasses. Above were uncrevassed snowfields whose surface was hard during the morning but very soft by mid-afternoon. Above 1000 m below the summit a minimum temperature of -15°C was recorded. Heim (1948, p. 60) flew round the mountain in 1947. His photographs (Heim, 1948 Figs. 65 and 66) show a valley glacier of considerable length on the northeast side and extensive flat-lying snowfields near the summit domes. Crevassing does not appear to be excessive. In 1952 Ghiglione climbed Coropuna by a glacier on the northwest side. The surface was pinnacle ice low down, and higher up the glaciers were crevassed "in a way without comparison with those of the Alps" (Ghiglione 1953?a, p. 175; 1954, p. 140). He described the summit as being formed of six rounded, ice-covered domes. The snow was knee-deep and as unstable as sand. The temperature on the summit was -23°C.

Ampato (6310 m) is a volcanic peak, probably extinct, with two summits. A uniform ice cover extends down to 5000 m on the south side and 5500 m on the north; a map from a survey of 1937 showed ice down to 4700 m on the south and 4900 m on the north (Oppenheim and Spann, 1946, p. 35). A photograph by Johnson (1930, Fig. 136) shows two short, steep, and broken glaciers. In 1946 a marker was placed near the terminus of a glacier on the east side (Oppenheim and Spann, 1946, p. 35; Spann, 1949?).

Cordillera Vilcabamba

The Cordillera Vilcabamba lies west-northwest of Cuzco, and extends about 150 km in an east-west direction between latitudes 13° and 14°S. The highest peaks, mostly of granite, reach over 6000 m. Some mountains are in groups and others are isolated peaks (Pièrre, 1954, p. 311).

Many climbing parties have commented on the snow conditions. A Franco-American expedition noted the "gigantic cornices" (Pièrre, 1954, p. 312). A British party was struck by the size of the cornices and by the strength of the seemingly flimsy bridges over crevasses. They also noted soft and deep snow on south-facing slopes and the astonishing steepness at which powder snow was stable, as compared to the Alps (Longland, 1958, pp. 11 and 16). A Swiss party also mentioned the huge cornices and the deep snow on southern slopes and the "extremely bad ice." They were as impressed by the steep snow-slopes as the British had been: "In the Andes the snow clings to gradients on which, in the Alps, only bare rock is encountered and the ice balconies cling to small terraces from which at home they would have thundered down much sooner" (Schatz, 1961, p. 168).

The rainy season is from October to May, and especially from January to March. The dry season is less pronounced than in the Cordillera Blanca; weather is usually fine early in the day but the mountains soon cloud over and snow may fall in the evening and during the night (Pièrre, 1953, pp. 123-124). The Franco-American expedition had to wait 22 days to get 48 hours of fine weather (Pièrre, 1954, p. 314).

The Cordillera may be divided into a western, a central, and an eastern group. The western group consists of Safra or Choquetira (5151 m), and Cerros Panta (5667 m), Soirococha (5355 m), and Pumasillo (5994 m). In 1911 glaciers on the south side of Panta rested on terminal moraines 60 to 90 m high, and the glacier descending from Soirococha to the Arma valley had a "patch of dark green woodland right up to its border" (Bowman, 1916, p. 214). Clark (1959, p. 112) has described a gently sloping glacier near Pumasillo [apparently on the west side and flowing south]: "a long ice river reminiscent of an Alpine glacier, it always seemed out of place. It was the only genuine valley glacier I ever saw in the Vilcabamba; all the others were steep enough to be more accurately termed icefalls . . ."

The central group consists of Cerro Salcantay (6274 m), Pico Soray or Umantay (ca. 5900 m), and unnamed ice-covered peaks northeast of Salcantay. The area was visited in 1911 by the Yale University expedition and many glaciers were photographed. Photographs by recent climbing expeditions are not useful for making comparisons. About 1945, bench marks were set up near the terminus of Incachiriascca Glacier (13°16'S, 72°36'W) on the south side of Salcantay, and Umantay Glacier at 13°15'S, 72°35'W (Spann, 1949?). Incachiriascca Glacier ended at 4595 m and was 1000 m to 1500 m long and up to 500 m broad. The lower part carried little debris but was much crevassed (Oppenheim and Spann, 1946, p. 30).

The eastern group rises above the right bank of the Río Urubamba, and consists of Veroncia, Helancoma, Media Luna, Yucay, and Saguasiray.

Cordillera Vilcanota

On the American Geographical Society 1:1,000,000 map the Cordillera Vilcanota extends for 150 km, on the World Aeronautical Chart 1:1,000,000 for about 50 km, and on the Peruvian Army 1:200,000 map the name does not appear. The name is here used for the mountains that extend eastward from the Nudo Ausangate and then south to the Nudo de Cunurana, overlooking the Cuzco-Puno railway.

The highest mountain in the group is Ausangate; estimates of its height range from 6153 m to 6550 m. It is a "great ice-clad mass with at least four summits" (Francis, 1955, p. 289). Other peaks in the Nudo Ausangate are Surimani, Lampa (5400 m), Caracol (5750 m), Cerro Cayangate (ca. 6000 m), Jatunhuma (6094 m), Colque Cruz, Jatunriti, and Yayamari (6007 m). The mountains are rugged and the glaciers short, steep, and broken. Ghiglione (1953?a, p. 178) mentions knee-deep snow on the southeast side of Ausangate and a "labyrinth of crevasses impossible to describe." A photograph on Cayangate shows men thigh-deep in snow (Hauser, 1961, p. 112). The glaciers appear in photographs (e.g. Hauser, 1959?, Pl. 24) to have receded from fairly small moraines and to carry little debris. The snowline is at about 5100 m on north-facing slopes and 4800 m on south-facing slopes (Ghiglione, 1953?a, p. 183). In 1945 an attempt by the Instituto Geológico del Perú to make observations on a glacier on Ausangate was prevented by prolonged bad weather (Oppenheim and Spann, 1946, p. 34).

The Nudo de Ayacachi (5435 m), an isolated ice-covered group lying north of the Nudo Ausangate, was climbed by a Spanish party in 1961 (Mendez, 1962). In 1945 a bench mark was set up near Paccopampa Glacier (13°26'S, 71°10'W), which is about 1 km long by 400 m wide and ends at 4580 m (Spann, 1949?). Two relatively recent end moraines had a lagoon between them and two older moraines lay beyond. Immature vegetation grew on the youngest moraine and in front of the glacier was a bare zone 8 m wide in 1945 (Oppenheim and Spann, 1946, p. 32).

East of the Nudo Ausangate the mountains turn southward; several peaks are ice-covered, the southernmost being the Nudo de Cunurana (5850 m).

Glaciers between the Cordillera Vilcanota and the Nudo de Apolobamba

East and southeast of the Cordillera Vilcanota and between this group and the Nudo de Apolobamba on the Bolivian border are several groups of little-known ice-covered mountains: the Nudo Allinccapac (13°55'S, 70°25'W), the Nudo de Quenamari (about 14°10'S, and 70°10' to 70°40'W), the Nudo de Sunipani (14°30'S, 70°10'W), and the Cordillera de Aricoma (14°10'S, and 69°50' to 70°10'W).

The Nudo Allinccapac contains about six ice-covered summits, the highest reaching nearly 5800 m. The mountains are extremely rugged, and there appears to be one moderate-sized glacier about 2 km long and several small ones (Francis, 1955, p. 286).

The highest peak in the Nudo de Quenamari is Quenamari Grande (5850 m). It may be in the rain shadow of the Nudo Allinccapac, for the snowline is very high--about 5500 m. From this peak, Katz (1955?, pp. 184-185) was astonished to see, 30 km to the east and centered about 14°05'S, 70°45'W, "an extensive and very wide plateau . . . covered by a large and coherent ice sheet from which several glaciers descend into lateral valleys." He thought it closely resembled some plateau icecaps in East Greenland and elsewhere. Francis (1959) has referred to this icefield as "Nevado de Quenamari." In 1956 a British party visited it; according to Croome (1957, p. 74) "nowhere else in the tropics is an ice-cap known to exist away from peaks or ridges . . . . In the Quenamari plateau the ice, which covers an area of about thirty-six square miles, appears stranded in flat country unconnected with sources of fresh ice." Part of the icefield was surveyed; it lies between 5500 m and 5800 m and is about 20 km by 5 km, terminating all around in precipitous ice cliffs. Some evidence for recession was found (Croome, 1957, p. 74; Francis, 1959, p. 14, quoting Jewell, 1957).

Other peaks in the area are isolated snow cones with desert ground between (Francis, 1955, p. 288). The Nudo de Sunipani and the Cordillera de Aricoma are little known; the Nudo de Sunipani is an isolated mass with several summits (Francis, 1955, p. 286).

Nudo de Apolobamba

The Nudo de Apolobamba straddles the Peru-Bolivia frontier north of Lago Titicaca. West of the Paso de Sina (14°39'S, 69°20'W) is a group of ice-covered summits that is wholly in Peru, dominated by Cerro Ananea (5842 m). To the east of the pass, only the extreme northwestern end of a long, heavily ice-covered range is in Peru. Much of the area was survyed during 1912 by the Peru-Bolivia Boundary Commission, 1911-1913. A map on the scale 1:250,000 was produced and many photographs of glaciers were obtained (Royal Geographical Society, 1918).

The Ananea group extends about 20 km westward from the Paso de Sina. Cerro Ananea itself supports several hanging glaciers and San Francisco Glacier, the "remnants of a valley glacier," about 1500 m long and 250 m wide. At the beginning of the century this glacier terminated above a precipice, immediately below which were the ruins of Spanish colonial buildings. The glacier margin was close to a lateral moraine, and an older moraine lay a short distance beyond (Pfordte, 1905, p. 498). At

this time, according to Sievers (1914, p. 250), the glacier was receding and had uncovered some ancient mine workings that had been covered up by a previous advance. The workings (which are mine tunnels and not "goldwäschen" as Sievers stated) are of unknown age, but they are believed to have been worked by the Spaniards. A 1912 photograph shows the ice margin some distance from an end moraine, with an older moraine beyond (Royal Geographical Society, 1918, p. 78). Further mine workings have been uncovered in recent years (Oppenheim and Spann, 1946, pp. 26-27). Bench marks were placed near the terminus in 1945 (Spann, 1949?).

Little information is available about the Peruvian mountains east of the Paso de Sina, such as the several summits of Cerro Palomani north of Lago Suches, and Cerro Chupi Orco. Some photographs, most of them with much temporary snow cover, were taken by the Boundary Commission.

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Photographic Sources

CORDILLERA BLANCA

Nevado Champará

Schneider (1937)
- P. 164. — Glacier ending at a lake, 1936.

Kinzl (1942)
- Pl. 2, Fig. 3. — Champará.

_______ and Schneider (1950)
- Pp. 58 and 102. — Same glacier as Schneider, 1937, p. 164.

Group Between the Quebrada Quitaracsa and the Quebrada Santa Cruz

Kinzl and Schneider (1950)
- Pp. 49, 60, 61, 86, 87, and 100. — Alpamayo.
- Pp. 62 and 63. — Santa Cruz.
- P. 59. — Pucahirca.
- Pp. 64 and 92. — Quitaraju, N side.
- P. 91. — Taulliraju, glacier terminus on E side.
- P. 97. — Milluacocha, glacier terminus on S side.
- Pp. 103 and 104. — Santa Cruz, NW side, glaciers entering the lake Rajucocha.

Kogan and Leininger (1954)
- Frontispiece and Figs. 14 and 22. — Alpamayo.

Oberlin (1955)
- P. 72. — Taulliraju.

Hauser (1959?)
- Pl. 23. — Alpamayo.

Ortenburger (1959)
- Pls. 9 and 10. — Santa Cruz Chico.
- Pl. 11. — Santa Cruz and Santa Cruz Chico, glacier terminus on E side.
- Pl. 12 — Alpamayo.

_______ and Dingman (1960)	
Pls. 18, 28, and 29.	Alpamayo.
Pl. 24.	Santa Cruz.
Pls. 25 and 26.	Quitaraju.
Stembridge (1964)	
Fig. 34.	Pucahirca.

Huandoy Group

Schlagintweit (1911)	
P. 85.	Huandoy, 1908.
Berge der Welt (1948)	
Pls. 57 and 60.	Huandoy.
Heim (1948)	
Photo 143.	Laguna Parrón and glaciers, aerial view, 1947.
Photo 144.	Three glacier termini near the head of Laguna Parrón, 1947.
Photo 161.	S side of Chacraraju; reconstituted glacier ending at moraine-dammed lake, 1947.
Kinzl and Schneider (1950)	
Pp. 50-51.	Huandoy group, W side, 1932.
Pp. 70, 71, 72, and 90.	Huandoy, 1932.
Pp. 65 and 101.	Artesonraju, 1940.
P. 68.	Chacraraju, 1932.
P. 98.	Terminal area of glacier damming Laguna Parrón, 1932.
P. 105.	Laguna Parrón, 1932.
Siri (1953)	
P. 444.	Pisco, summit area.
P. 445.	Huandoy, summit area; Huandoy group, aerial view.
Michael (1955)	
P. 11.	Yanapaccha, summit cornice.
P. 17.	Huandoy.

Oberlin (1955)	
P. 72.	Chacraraju, Pyrámide, and Huandoy.
Ortenburger (1955)	
P. 26.	Huandoy group, S side; Chacraraju.
P. 35.	Yanapaccha, W side.
______ (1959)	
Pl. 14.	Chacraraju.
Stembridge (1964)	
Figs. 31 and 32.	Huandoy.

Huascarán Group

Enock (1908)	
P. 176.	Huascarán, N side, 1904.
Schlagintweit (1911)	
P. 83.	Chopicalqui [?], 1908.
P. 85.	Huascarán, glacier on N side, 1908.
Sievers (1914)	
Photos 49 and 50.	Huascarán, glacier on N side, 1909.
Heim (1948)	
Photo 132.	Huascarán, S side, aerial view, 1947.
Photo 151.	Huascarán, glacier on N side, 1947 [cf Sievers, 1914, Photo 49].
Fig. 156.	Huascarán, S side, 1947.
Kinzl and Schneider (1950)	
P. 52.	Huascarán, W side, 1932.
P. 67.	Huascarán, glacier on N side, 1932.
P. 69.	Chopicalqui, N side.
P. 73.	Huascarán, W side, 1936.
Michael (1955)	
P. 14.	Chopicalqui.
P. 18.	Huascarán.
Ortenburger (1955)	
P. 30.	Chopicalqui, NW side.
P. 34.	Chopicalqui, summit area.
______ (1959)	
Pl. 16.	Huascarán, SW side.

Hechtel (1962)
Pl. 73. — Chopicalqui.

McDowell (1962)
Pp. 854, 856, 863, and 872. — Huascarán.

Contrahierbas Group

Sievers (1914)
Photo 46. — Glacier on Contrahierbas.

Kinzl and Schneider (1950)
P. 74. — Contrahierbas, summit ridge.
P. 93. — Contrahierbas, N side.

Ortenburger (1959)
Pl. 15. — Contrahierbas, W side.

Group Between the Quebrada Ulta and the Quebrada Honda

Sievers (1914)
Photo 39 and 40. — Atlante Glacier, 1909.

Heim (1948)
Photos 152, 153, and 155. — Glacier terminus on Tulparaju.

Kinzl (1949)
Pl. 10. — Glacier on SW side of Tulparaju.

________ and Schneider (1950)
P. 53. — Panorama of the W side of the group, 1932.

Oberlin (1955)
P. 72. — Unnamed peak above the Quebrada Ulta.

Ortenburger (1959)
Pl. 13. — Ulta.

Hechtel (1962)	
Pls. 66, 67, and 69.	Ulta.
Bernays (1963)	
Pl. 29.	Tulparaju.
Carter and Humphreys (1963)	
Pls. 35, 39, and 40.	Paccharaju.
Pl. 36.	Peak, 5460 m, and the lake Pacchacocha.
Pls. 38 and 41.	Ichic Churihuauqui.
Pl. 44.	Nevado de Copa.
Humphreys (1963)	
P. 10.	Ichic Churihuauqui.
P. 12.	Paccharaju.
P. 16.	Nevado de Copa.

Group between the Quebrada Honda and the Quebrada Cayesh

Berge der Welt (1948)	
Pl. 62.	Pucaranra and glacier ending in lake.
Heim (1948)	
Photo 162.	Laguna Cohup [Palcacocha]; aerial view, 1947, six years after the break-out.
Kinzl (1949)	
Pl. 9.	Glacier ending in the lake Bayococha, 1932.
________ and Schneider (1950)	
P. 78.	Chinchey, E side, 1936.
P. 79.	Tocllaraju, summit area, 1939.
P. 80.	Pucaranra, glacier ending in lake, 1939.
P. 81.	Palcaraju, 1939.
P. 82.	Ranrapalca, 1940.
P. 95.	Copap [?], W side, showing glacier termini, 1939.
P. 96.	Yanacocha Glacier, Quebrada Honda, 1936.
Pp. 106 and 107.	Palcaraju and Pucaranra, with Palcacocha before the break-out, 1939.
P. 108.	Palcaraju and glacier descending to Palcacocha, before the break-out, 1940.

Egeler and de Booy (1955)	
Pp. 166 and 173.	Cayesh.
P. 180.	Pucaranra, and glacier ending near the lake Bayococha.
Ortenburger (1959)	
Pl. 19.	Tocllaraju.
Pl. 20.	Palcaraju.
Pl. 21.	Pucaranra.
Stewart (1961)	
P. 204.	Three photos of Cayesh.

<u>Group Between the Quebrada Cayesh and Punta Yanashallash</u>

Kinzl (1949)	
Pl. 2.	Huantsán, E side, 1936.
Pl. 3.	Uruashraju, glacier termini, 1932.
Pl. 4.	Uruashraju, same termini as Pl. 3, 1936.
Pl. 5.	Rurec, glacier on W side, 1936.
Pl. 6.	Rurec, same glacier as Pl. 5, 1939.
Pl. 7.	Glacier on SW side of Huantsán, 1936.
________ and Schneider (1950)	
Pp. 54-57.	Panoramas of the group from the W, 1940 and 1936.
P. 8.	Huantsán, 1936.
Egeler and de Booy (1955)	
Pp. 101, 108, 132, 141, and 149.	Huantsán.
P. 140.	San Juan group.
Ortenburger (1959)	
Pls. 17-19.	Huantsán.

<u>South of Punta Yanashallash</u>

Kinzl and Schneider (1950)	
P. 84.	Pongos, 1940.
P. 85.	Caullaraju, 1936.
P. 110.	Pucaraju and Yanamarey, SW sides, 1940.
Egeler and de Booy (1955)	
P. 64.	Pongos, 1952.

Giobbi (1964)

Pls. 49-52.	Caullaraju group.

GLACIERS EAST OF THE CORDILLERA BLANCA

Sievers (1914)

Photo 2.	Cumbre [Nevado] de Acrotambo.

CORDILLERA HUAYHUASH

Sievers (1914)

Photo 11.	Glaciers behind "Suirokocha," 1909 [may be glaciers behind Quesillococha, E side of Sarapo].
Photo 12.	Yerupajá, NE side.

Kinzl (1937)

Pl. 3.	Yerupajá, NE side.
Pl. 4.	Yerupajá, S side.
Pl. 5.	Panorama, E side of Sarapo group.
Pl. 6.	Sarapo and Juraucocha, SW sides.

Schneider (1937)

Pl 168.	Sarapo and Juraucocha [same as Kinzl, 1937, Pl. 6].
P. 169.	Suilá.

Berge der Welt (1948)

Pl. 64.	Yerupajá.

Heim (1948)

Facing p. 88.	Jirishhanca, W side.
Photos 125, 127, 128, 129, and 131.	Yerupajá from the air, 1946.
Photo 126.	Glacier reaching the lake Solterahancacocha, W side of Jirishhancá, 1946 [may be misnamed, cf photo 136].
Photo 130.	Siula from the air, 1947.
Photo 136.	Glacier from Yerupajá, ending in Solterahancacocha, 1947.
Photo 139.	Yerupajá, N side.

Bell (1951)

Pp. 33-36.	Yerupajá.

Matthews and Harrah (1951)	
Pp. 24 and 30.	Yerupajá.
Kinzl (1955b)	
Contains over 50 photographs from 1936 and 1954.	
Klier (1955?)	
Pl. 53.	Sarapo and Siulá.
Pl. 54.	Rasac; glacier ending in Sarapococha.
Pl. 55.	Yerupajá, NE side.
Pl. 56.	Jirishhanca Chico [El Toro].
Oberlin (1955)	
P. 72.	Jirishhanca to Siulá, aerial view.
Klier (1959?)	
Pls. 18-22.	Jirishhanca group.

HUAGARUNCHO AREA

Jenks (1941)	
Pp. 161 and 169.	Huagaruncho, S face.
P. 168.	W end of main ridge.
Bishop (1943)	
P. 82.	Huagaruncho from Jancahuay [Peak 33].
P. 83.	Jancahuay [Peak 33] and Incatana [Peak 32], E sides.
Oberlin (1955)	
P. 72.	Huagaruncho, aerial view.
Westmacott (1959?)	
Pl. 15.	Huagaruncho, S face [from same point as Jenks, 1941, p. 169].
Pl. 16.	Huagaruncho, N face.
Pl. 17.	Huagaruncho, summit.

CORDILLERA RAURA

Sievers (1914)	
Photo 8.	Glacier terminus at the lake Caballococha, 1909.
Photo 10.	Glaciers, NE of Laguna Viconga, 1909.

Miller (1929)

Figs. 11, 12, and 14.	Small glaciers W of the lake Acacocha (10°47'S, 76°32'W), 1927.
Fig. 17.	Small glacier, NW side of Lago Punrún.
Fig. 18.	Glacier at Lago Potosí (10°28'S, 76°45'W).
Fig. 19.	Glacier at Lago Santa Ana (10°26'S, 76°45'W).
Fig. 23.	Glaciers above Lago Potosí.
Fig. 26.	Glaciers W of the lake Patarcocha (10°23'S, 76°46'W).

Jenks (1941)

P. 160.	Peak 10 (10°26'S, 76°46'W), SE side, 1939.

Broggi (1943)

P. 69.	"Raura" Glacier, Laguna Santa Ana [reproduction of Miller, 1929, Fig. 19, and photo from same point in 1943].

Cardich (1955)

P. 123.	Glacier, "source of the Amazon," 1953 or 1954.
Pp. 125 and 127.	Glaciers in Raura group, 1953 or 1954.

"ANDES CENTRALES"

Hauthal (1911) [Photos taken in 1908.]

Photos 77 and 78.	Glaciers NW of the lake Morococha.
Photo 81.	Toldorumi and other mountains, distant.
Photo 83.	Toldorumi, glacier on S side.
Photo 84.	Glacier on Toldorumi.

Showalter (1930)

Pls. 1, 7, and 12.	Glaciers near the Central Railway.

Broggi (1943)

P. 75.	Pincoyuyoc, photograph of 1862 painting.
Pp. 76 and 77.	Pincoyuyoc in 1923 and 1942.
Pp. 78-80.	Paragte in 1917, 1923, and 1942.
Pp. 82 and 83.	Glaciers near Estación de Galera, 1890 and 1942.

Oppenheim and Spann (1946)	
Pp. 8, 12, 17, and 19.	Yanasinga Glacier.
Berge der Welt (1948)	
Pl. 64.	Cerro Rajuntay, glaciers on N side [N of railway].
Heim (1948)	
Photos 98, 99, and 102.	Tuyujuto, 1946.

SIERRA DE HUAYTAPAYANA

Shippee (1933)	
P. 111.	Ice-covered peaks near Huancayo, aerial view.
P. 120.	Glacier on Lasontai, aerial view.
Heim (1948)	
Photos 89-91 and 94.	Lasontai, 1946. [Photo 94 is same as Shippee, 1933, p. 120].
Harrison (1951)	
Photos 1, 2, 4, and 5.	"Nevados de Chuspe."
Photo 7.	Condorvasha.
Dunn (1955)	
P. 39.	Lasontai, NW side.
P. 43.	Yanaüccha and Ancon.

CORDILLERA OCCIDENTAL DE LA COSTA

Cook (1916)	
P. 490.	Coropuna, from high plateau.
Bingham (1922)	
Pp. 12, 24, and 32.	Coropuna.
P. 78.	Sara-Sara.
Johnson (1930)	
Figs. 123, 132, and 133.	Chachani.
Figs. 134 and 136.	Ampata.
Heim (1948)	
Photos 65 and 66.	Coropuna, aerial view, 1947.
Photo 67.	Ampata, aerial view, 1947.
Photo 71.	Chachani, aerial view, 1947.

Ghiglione (1953b)

Fig. 46.	Solimana, N side.
Figs. 52 and 56.	Coropuna.

CORDILLERA VILCABAMBA

Bingham (1913)

Pp. 560 and 563-565.	Glaciers on Salcantay and in upper Aobamba valley.

Bowman (1916)

Fig. 186.	Cordillera Vilcabamba, western group.
Fig. 193.	Panta and glacier [on SE side?]

Cook (1916)

P. 477.	Veronica.
Pp. 480, 482, 485, and 487.	Glaciers near the Urubamba valley.

Bingham (1922)

P. 170.	Glacier terminus between Cuzco and Uiticos.
P. 210.	"Grosvenor" Glacier terminus, Salcantay.

Shippee (1933)

P. 89.	Summit of Veronica, aerial view.

Oppenheim and Spann (1946)

P. 51, photo 12.	Salcantay.
P. 55, photo 14.	Salcantay.
P. 53, photo 13.	Incachiriascca Glacier, Salcantay.
P. 59, photos 15-17.	Incachiriascca Glacier, Salcantay.

Bingham (1948)

P. 138.	Glacier terminus between Soray and Salcantay.
P. 234.	Salcantay.

Heim (1948)

Photos 200 and 212-215.	Salcantay.
Photos 210 and 211.	Soray (Umantay).
Photo 214.	Unnamed mountain NE of Salcantay.

Ayres (1953)

Pp. 56 and 57.	Salcantay, summit, and aerial view from NE.

Ghiglione (1953b)	
Fig. 54.	Scray (Umantay).
Figs. 55 and 57.	Salcantay.
Michael (1953)	
Pp. 33, 34, and 38.	Salcantay.
Oberlin and Matthews (1953)	
P. 390	Salcantay, aerial view.
Pièrre (1953)	
Pp. 49 and 50.	Panorama of the cordillera, aerial view.
_______ (1954)	
Pp. 310 and 311.	Salcantay.
Matthews (1957)	
Pp. 67 and 68.	Pumasillo group.
Longland (1958)	
Pp. 14 and 15.	Pumasillo.
Clark (1959)	
Pp. 69, 77, 112, 160, 176, and 177.	Pumasillo group.
Schatz (1961)	
Pls. 48-50.	Pumasillo, aerial view, 1957.
Naylor (1963)	
Pp. 12 and 13.	Pumasillo group.
Hearfield (1964)	
Figs. 13-18	Upper parts of Mitre, Sacsarayoc, Pumasillo, and Lasonayoc,

CORDILLERA VILCANOTA

Ghiglione (1953?a)	
Pls. 47-49.	Ausangate.
Pls. 50 and 51.	Unnamed 6000-m peak between Ausangate and Cayangate.
Pl. 52	Cayangate III, NE face.
_______ (1953b)	
Figs. 8 and 9.	Ausangate group.

Figs. 10 and 14. — Ausangate.

Figs. 12, 17, 19, and 24. — Glaciers on the S, SW sides of Ausangate.

Fig. 43. — Cordillera Vilcanota

Rebitsch (1953)

P. 80. — Ausangate.

März and others (1956)

Pp. 8, 11, 13, 14, 22, 23, and 24. — Ausangate.

P. 40. — Colque Cruz.

Pp. 64, 65, 67, and 68. — Cayangate III, IV, I, and IV.

Jewell (1957) [Not seen; reference from Francis, 1959, p. 140] "Nevado de Quenamari" icefield.

Hauser (1959?)

Pl. 24. — Cayangate I-IV, showing glacier termini.

Pl. 25. — Jatunhuma.

Jervis (1959)

P. 38. — Ausangate and the range to the NE, aerial views, 1952.

Hauser (1961)

P. 96. — Caracol, S side, showing glacier termini.

P. 97. — Cayangate, showing glacier termini.

Mendez (1962)

Pp. 17 and 18. — Nudo de Ayacachi.

Weaver (1964)

Pp. 256 and 257. — Cunurana.

NUDO DE APOLOBAMBA

Royal Geographical Society (1918) [Photos taken in 1912.]

P. 70. — Palomani Grande.

P. 71. — Palomani peaks.

P. 78. — San Francisco Glacier terminus.

P. 79. — Calijón.

P. 82.	Ananea.
P. 83.	East end of Ananea group.
P. 86.	Glacier near Paso de Sina.
Oppenheim and Spann (1946)	
P. 41, photo 1.	San Francisco Glacier, panorama.
P. 47, photo 4.	San Francisco Glacier front.
Pp. 49-50, photos 5-11.	San Francisco Glacier, details of front and of uncovered mine workings.
Heim (1948)	
Photos 81, 83, and 85.	San Francisco Glacier.
Photo 82.	Ananea, near summit.
Photo 84.	Calijón.

Note: According to Pan American Union (1964), aerial photographs of most of the country have been taken since 1953. The majority of these photos are held by either the Instituto Geográfico Militar or the Servicio Aerofotográfico Nacional, both in Lima.

Map Sources

Journal, Swiss Foundation for Alpine Research (1961) Vol. 3, No. 10.
Accompanying map. Sud Peru: Carta Orografica Elaborata Secondo le Indicazioni di Piero Ghiglione, 1:1,000,000.

Cordillera Blanca

Kinzl (1942)
Accompanying map. Cordillera Blanca y el Callejón de Huailás (Peru), 1:100,000. [Shows the N half of the cordillera.]

______ (1949)
Accompanying map. Cordillera Blanca (Perú), Südteil, 1:100,000. [Shows the S half of the cordillera.]

______ (1950)
Accompanying map. Cordillera Blanca (Perú), 1:200,000. [Based on 1932, 1936, and 1939 surveys.]

______ and Schneider (1950)
Accompanying map. [Same as Kinzl, 1950, accompanying map.]

Swiss Foundation for Alpine Research, Zurich. Anden von Peru, Cordillera Blanca und Huayhuash, 1952, 1:300,000.

Cordillera Huayhuash

Kinzl, Schneider, and Ebster (1942)
Accompanying map. Cordillera de Huayhuash (Perú), 1:50,000. [Topographic map.]

Kinzl (1955b)
Accompanying map. [Same as Kinzl, Schneider, and Ebster, 1942, accompanying map.]

Huagaruncho Area

Jenks (1941)
P. 163. Map of the Huagaruncho Massif [1:250,000].

Westamacott (1959?)
P. 67. Huagaruncho Massif (Peru) [1:120,000]

Cordillera Raura

Miller (1929)
Pl. 1. — Topographical Survey of the Sources of the Marañon and Mantaro Rivers (Central Peru), 1:200,000. [Shows part of the Raura Cordillera and a narrow strip of country to the SE.]

Jenks (1941)
P. 158. — Map Showing the Yerupajá, Raura and Gaico Ranges [1:500,000].
P. 163. — Map of the Huagaruncho Massif [1:300,000].

Kinzl (1955b)
Accompanying map. — Cordillera de Huayhuash (Perú), 1:50,000. [Shows part of the plateau glacier E of Laguna Viconga.]

"Andes Centrales"

Heim (1947) [Not seen: reference from Heim, 1948, p. 93.]
Accompanying map. — [Topographic and geologic sketch map of the Tuyujuto area, 1:250,000.]

Sierra de Huaytapayana

Harrison (1947)
Accompanying map. — The Eastern Andes of Central Peru, 1945 [1:400,000].

Dunn (1955)
P. 40. — The Lasontai Area, Province of Junin, Peru [1:100,000].

Cordillera Occidental de la Costa

Servicio Geográfico del Ejército, Lima. Carta Nacional, 1:200,000. [After 1945 the Servicio Geográfico del Ejército became the Instituto Geográfico Militar.]

14-f	Andahuaylas, 1943.	16-g	Chivay, 1942.
14-g	Abancay, 1946.	16-i	Lampa, 1928.
14-h	Cotabambas, 1943.	17-e	Arequipa, 1940.
15-f	Alca, 1947.	17-g	Ichuña, 1930.
15-g	Sto. Tomas, 1945.	18-d	Candarave, 1938.
16-f	Viraco, 1947.	19-c	Pachia, 1933.

U. S. Air Force, St. Louis, Operational Navigation Chart, 1:1,000,000.
ONC 1136. Lake Titicaca, 1963.

Cordillera Vilcabamba

Instituto Geográfico Militar, Lima. Carta Nacional, 1:200,000.
13g Curahuasi, 1946.
13h Anta, 1946.
13i Cusco, 1943 [shows S edge of range].

Oppenheim and Spann (1946)
P. 57. Situación de los Nevados Salcantay y Umantay, ca. 1:20,000.
P. 63. Situación del Nevado Paccopampa y Laguna Ampatuni, ca. 1:20,000.

Clark (1959)
P. 47. Vilcabamba [1:500,000--scale given on map is wrong].
P. 98. The Pumasillo Massif (Lat 13°10'S. Long 72°52'W.) [1:200,000].

Fantin (1959)
P. 213. Cordigliera di Vilcabamba ovvero dell'Urubamba "Gruppo Est" [1:300,000]. [Sketch map showing glaciers of the E group.]

Hearfield (1964)
P. 42. Pumasillo Group of the Cordillera Vilcabamba [1:150,000].

Cordillera Vilcanota

American Geographical Society, New York. Hispanic America, 1:1,000,000.
S.D-19 Puno-Río Beni, 1927.

Servicio Geográfico del Ejército, Lima. Carta Nacional, 1:200,000.
14j Sicuani, 1943.

Hauser (1959?)
P. 93. Cordillera Vilcanota, [ca. 1:500,000].

Jervis (1959)
P. 40. Cordillera Vilcanota Sketch Map [1:96,000].

U. S. Air Force, St. Louis. Operational Navigation Chart, 1:1,000,000.
ONC 1136 Lake Titicaca, 1963.

Glaciers Between the Cordillera Vilcanota and the Nudo de Apolobamba

American Geographical Society, New York. Hispanic America, 1:1,000,000.
S.D-19 Puno-Rio Beni, 1927.

Francis (1955)
P. 287. The Allinccapac Group [1:100,000].

Mendez (1962)
Pp. 11-12. Nudo Ayacachi. [Large-scale sketch map, scale unknown.]

Nudo de Apolobamba

Royal Geographical Society (1918)
Accompanying map. The Peru-Bolivia Frontier, Sheet 1: Río Suches to Río Heath, 1:250,000 [topographic map].

Servicio Geográfico del Ejército, Lima. Carta Nacional, 1:200,000.
15-1 Cojata, 1932.

U. S. Air Force, St. Louis. Operational Navigation Chart, 1:1,000,000.
ONC 1136 Lake Titicaca, 1963.

GLACIERS OF BOLIVIA
AND OF CHILE NORTH OF LATITUDE 23°S

In Bolivia and contiguous parts of Chile the Andes are at their widest. The Cordillera Oriental overlooks the Amazon basin and the Cordillera Occidental extends along the Chile-Bolivia border. The high, barren Bolivian Altiplano, averaging about 3700 m above sea level, lies between. The firn limit rises from about 4900 m in the Nudo de Apolobamba to 5300 m in the Cordillera Real, probably because of a southward decrease in precipitation.

The Cordillera Occidental consists of isolated volcanic cones. The humid winds from the Amazon basin do not reach these peaks, with the exception of the highest, Nevado Sajama (6520 m), which has true glaciers. On other peaks the climate is so dry that they have only inactive ice bodies or permanent snow beds, although several exceed 6000 m, where the air temperature rarely if ever rises above freezing.

The best available maps of different parts of the area vary greatly in age and quality. There is little consistency in the usage of the generic names "Nevado," "Pico," "Cerro," "Monte," or even "Volcán." The names used here are taken from the most recent sources; because large-scale maps give no generic names for the peaks in the Nudo de Apolobamba and the Cordillera Real, none are used here either in those ranges.

Not many scientific observations have been made on the glaciers. Excellent cartographic work was done on part of the Cordillera Real by the 1928 Alpenverein expedition, and in the Nudo de Apolobamba some measurements of flow rates and surveys of tongues have been made by climbing parties in recent years. A glaciological program was planned for the International Geophysical Year in the Cordillera Real.

Nudo de Apolobamba

The Bolivian section of the Nudo de Apolobamba extends for about 50 km in a southeasterly direction and is separated into three ice-covered groups by ice-free passes. Parts of the northern group were tied in with the survey of the Peru-Bolivia Boundary Commission of 1911-13 and some photographs were taken. Most of the range, however, remained little known until Italian, German, and British climbing expeditions went there in the late 1950's.

The British party worked in the northern group. The snouts of fifty-one glaciers were surveyed, and measurements made of flow rates. Both retreating and advancing glaciers were found: "The fronts of many

glaciers were reaching past old terminal moraines and covering plants which were at least ten years old." (Melbourne, 1960a, p. 456). Snow conditions were apparently similar to those in the Peruvian Andes: huge overhanging cornices on the ridges and summits and "exasperatingly deep, soft snow on south-facing slopes" (Melbourne, 1960a, p. 457; see also Melbourne, 1960b, p. 177; Bratt, 1960, p. 39). On north-facing slopes a man could walk with crampons on the ice crust in the morning and sink up to his knees in soft snow in the afternoon. Most mornings were clear but nearly every afternoon clouds moved in from the Amazon lowland to the north (Melbourne, 1960b, p. 178). The "Azucarani" Glacier was found to have stepped crevasses every 50 m or so, with ice cliffs 6 m to 10 m high. The ice cover in general was very heavy (Melbourne, 1960a, p. 456).

The German party climbed in all parts of the range, which they have described as rugged with many large glaciers. On climbing the mountains they were struck by the abrupt transition from ice-free ground to complete ice cover. Huge icefalls were encountered, and the summit areas of Cololo (5915 m) and Chupi Orco (6040 m) were covered with knee-deep powder snow (Karl, 1958, pp. 100-102). The snowline lay between 4800 m and 5000 m.

Between the Nudo de Apolobamba and the Cordillera Real, Retamoso (1931, p. 204) reported glaciers on the Cordillera Huallpani and the Cordillera Callinzani; these ranges appear to be north of Ancoraimes on Lago Titicaca.

Cordillera Real

The Cordillera Real falls conveniently into two sections: northwest and southeast of the railway to La Paz. According to Nelson (1964, p. 217) the only available map is largely inaccurate [presumably Troll, 1931, and Echevarría, 1959]. On the American Geographical Society 1:1,000,000 map (Sheet S.E-19, 1922) the Cordillera Real is shown as including the Cordillera Quimsa Cruz and the Cordillera Santa Vera Cruz, but in general usage today it is considered to extend only to the Río de la Paz. The firn limit is at 5300 m to 5400 m on the west, and higher on the east (Ahlfeld and Branisa, 1960, p. 153).

The northern section extends from near 15°50'S to 16°20'S and includes the following peaks: Illampu (6362 m), Ancohuma (6388 m), Casiri (5828 m), Chaeroco (6127 m), Chachacomani (6074 m), Condoriri (5656 m), Caca Aca or Huainapotosi (6094 m), and Chacaltaya (5380 m). According to Conway (1899b, p. 18) snow cover is almost uninterrupted throughout, though one and perhaps two passes are free in summer. About 15 km to the north of this group is an isolated ice-covered peak near the village of Yani (Retamoso, 1931, p. 204).

In 1900 Conway nearly reached the summit of Ancohuma via the "Haukaña" Glacier [Glacier No. 1 of the Troll and Finsterwalder map, 1935]. This glacier descended in five icefalls and an abandoned gold mine lay near the snout. Conway remarked on the "curiously dry, stony appearance of the ice," which he believed was caused by the rapidity of evaporation. He also noted that despite the overhanging seracs and the "incredibly steep ice slopes there was . . . no sign or sound of movement, such as the glaciers of the Alps are always emitting. In all the days we spent among the great ice-falls of Mount Sorata [Illampu-Ancohuma massif] I never saw or heard the fall of the least fragment of ice." (Conway, 1901, pp. 181 and 184). He noted enormous crevasses on the upper glacier, but a snow bridge 3 m to 6 m below the edge was always present (Conway, 1901, p. 189). Waist-deep snow was encountered on the final peak and "No amount of treading would make the snow bind. It poured over the feet and about the legs like sand. How it maintained its position at all on the steep incline was a mystery" (Conway, 190 , pp. 232-233).

Dienst (1927, p. 103) mentioned that above 5400 m on Ancohuma the surface changed from compact snow to deep powder snow. His party was glad to find an avalanche field where they could jump from one ice block to another. On Caca-Aca he found a field of low ice pinnacles; higher up the snow was almost impassably soft except where it lay in shadow (Dienst, 1927, p. 100).

The Illampu-Ancohuma-Casiri area was studied and surveyed by the 1928 Deutsche und Österreichischen Alpenvereins expedition, and a topographical map on a scale 1:50,000 was made on which the altitudes of most of the ice tongues were shown. End moraines lay close to the glacier tongues and older ones much farther away; for example, two moraines lay within 300 m of the margin of the glacier flowing southwest from Humahallanta and others were 5 km to 6 km distant (Troll and Finsterwalder 1935, p. 397). Hörtnagl (1930), who climbed Illampu and Casiri, referred repeatedly to the deep powder snow at higher elevations.

East of Casiri the Negruni and Chaeroco valleys and their glaciers were surveyed by a British party in 1962 and an outline map on a scale of about 1:35,000 was made. Considerable shrinkage was observed on all the main glaciers, and at the head of the Chaeroco valley was a "vast and impressive moraine" well in advance of the glacier (Hunter, 1963, p. 222).

The ice tongues in the Chacaltaya area are mostly rather small, according to Hauthal (1911, p. 101), but he found one extensive, nearly flat firn field with a maximum elevation of 5000 m. Chacaltaya Glacier, 30 km from La Paz and near the road, was selected for studies during the International Geophysical Year. Ice recession, erosion, and transport

of material were to be studied (Escobar, 1956, p. 6). The results of these observations are not known to the author.

The southern section of the Cordillera Real, between the railway and the Rio de la Paz, consists of widely-separated ice-covered summits, among them, Huaillara, Chicani, Taquesa, Mururata (5781 m) and Illimani (6457 m). Little information is available about any except Illimani. In 1827 Pentland (1835, p. 85) found the lowest snow patch in late December at 5140 m. The lowest glaciers, or snow in ravines, reached 5980 m. These altitudes can be compared with that given for the "Lake of Illimani," 4862 m.

Conway (1899b, p. 23) found signs of prehistoric habitation and agriculture on Illimani much higher than existing villages, and one ruined village was at the very edge of a small glacier. This may perhaps be evidence for a previous warmer period in the area. In his ascent of Illimani, Conway (1899a, p. 513) noted the huge cornices and a summit snow plateau on which the snow was "hard as a board."

In 1908 the glaciers on the west side terminated at 4800 m; on the eastern side the precipitation was heavier and they reached lower. The ice margin had receded a considerable distance from large end moraines, and recession was continuing (Hauthal, 1911, p. 115).

According to Ertl (1953?, p. 156) the weather on Illimani is best from April through June; in July and August the cold is intense, in September and October sudden snowstorms are likely, and in November through March is the rainy season. In May he encountered powder snow a meter deep and overhanging cornices on alternating sides of the ridge (Ertl, 1953, p. 153). Dienst (1927, p. 96) noted meter-high ice pinnacles on Illimani and a variety of surfaces including glare ice, soft snow, and hard crusted snow alternating with soft snow.

Cordillera Quimsa Cruz and Cordillera Santa Vera Cruz

Southeast of the Río de la Paz are the Cordillera Quimsa Cruz and the Cordillera Santa Vera Cruz. The Cordillera Quimsa Cruz has unbroken ice cover for about 30 km. From north to south the peaks are: Cerro Imaculado (ca. 5600 m), Nevado Atorama (ca. 5700 m), Cerro Gigante (ca. 5800 m), Jachacunucollo (ca. 5950 m), Cerro San Juan, and Monte Blanco. Cerro Yunque lies to the north of the main range and several ice-covered peaks lie to the east of the range.

The ice cover is most extensive at the southern end of the range, and only in the southeast do true valley glaciers exist. In 1910 the glaciers were in rapid retreat and freshly abandoned end moraines were

present everywhere. On the western side the glaciers extended to about 4800 m and the firn limit was at about 5300 m (Herzog, 1913a, p. 194).

Despite the lower precipitation on the western side of the range, the snowline and the lower limit of the glaciers lie at about the same altitude on both sides, according to Ahlfeld (1932, p. 80). On Atorama he encountered ice pinnacles a meter high, which he was told appeared only during the winter months. He crossed the range between Gigante and Jachacunucollo, and described the firn field as completely flat and almost crevasse-free, and the glacier tongues as very steep and broken. He noted many signs of glacier retreat (Ahlfeld, 1932, p. 89).

The Cordillera Santa Vera Cruz is 20 km long, and reaches about 5600 m in "Fortuna" Peak. It carries the southernmost glaciers in the eastern cordillera of Bolivia, mostly on the south and west sides (Prem, 1945, p. 322). In published photographs small, hanging glaciers can be seen, but Prem (1945, p. 323) mentions a larger one over which he traveled and which was receding.

Cordillera Occidental

The Chile-Bolivia border runs along the Cordillera Occidental. The firn limit is extremely high, at least 6000 m, and of the several peaks exceeding this altitude only Sajama is known to carry true glaciers.

At the end of summer (March) 1827, Pentland (1835, p. 73) observed several snow-capped peaks in the vicinity of Tacora village. On "Chipicani" [above the village to the northeast], he estimated the snowline to average 5170 m, 119 m higher on the north face than on the south face (p. 85). This, however, is not consistent with his figure for the height of the mountain, 5181 m, and both figures appear too low. On a recent map of the Instituto Geográfico Militar de Chile [Sheet 1770, General Lagos], the village of El Tacora lies between Nevado Chupiquina (5787 m), which is probably Pentland's "Chipicani," and Volcán Tacora (5988 m), where the snowline is above the summit (Kessler, 1963, p. 168).

Southeast of Volcán Tacora and about 18°10'S, 69°10'W, are the twin peaks of the Nevados de Payachata: Pomarape (6240 m) and Parinacota (6330 m), through which the international boundary runs. According to Prem (1931, p. 234), Payachata Chico [Pomarape] carries permanent snow but no glaciers. However, a photograph by the same author (Prem, 1940, p. 32) of "Northern Payachata" shows a conical mountain with what appear to be a summit glacier and thin glaciers on its flanks. Payachata Grande [Parinacota] appears snow-free on the eastern side when seen from a distance, but in fact carries ice beneath a covering of ash and sand (Prem, 1931, p. 234). The photographs by Gerstmann were unfortunately taken when the two mountains were heavily snow-covered. According to Ahlfeld

and Branisa (1960, p. 153) the mountains carry permanent snow down to 5900 m.

About 25 km to the east is Sajama (6520 m), the highest mountain in Bolivia. It has an ice-covered summit, and what Prem (1931, p. 226) described as "true valley glaciers" on its flanks. Vincurata Glacier on the west side ended at 5500 m, and Huchushuailla Glacier on the southeast reached 4750 m, probably because it was protected by debris. According to Ahlfeld and Branisa (1960, p. 153), however, no glacier reached below 5400 m. At the beginning of October, 1939, Prem reached the summit in a "furious west wind." On the way up he encountered nieve penitente and ice buried under scree. The summit was a plateau, probably an ice-filled crater, and the surface was covered with sastrugi (Prem, 1945, pp. 330-331). Ertl (1953?, pp. 168 and 169), who also reached the summit, recorded a temperature of -26°C at about 5750 m in mid-July. Parts of the steep ice slope round the "immense" summit plateau were covered with meter-high ice pinnacles.

South of the Payachatas, Pentland (1835, p. 72) noted a very regular volcanic cone called Gualatieri, whose summit reached about 1500 m above the March snowline. This must have been Volcán Guallatiri (6060 m), situated at 18°25'S, 69°10'W, 5 km within Chile, which Ogilvie (1922, p. 96) claimed carried permanent snow. Immediately east of Volcán Guallatiri and on the international border are the Nevados de Quimsachata: Cerro Acotango (6050 m) and Cerro Capurata (5990 m).

Further south the snowline reaches its maximum elevation in the vicinity of Cerro Auncanquilcha (6180 m; 21°15'S, 68°30'W) which carries no permanent snow (Ahlfeld and Branisa, 1960, p. 153). Only a short distance to the south the lower summits of Volcán Uturunco (5900 m; 22°15'S, 67°12'W) and Cerro Lipéz (5850 m; 21°50'S, 66°50'W) have some permanent snow (Ahlfeld and Branisa, 1960). Volcán Licancábur (5921 m) on the international border in the extreme south of Bolivia had virtually no snow on 22 November 1953 (Rudolph, 1955, p. 164).

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Nudo de Apolobamba

Royal Geographical Society (1918)

P. 91.	Glaciers in Pelechuco Pass, 1911.
P. 187.	Palomani Grande from Sina Pass, 1911.

Karl (1958)

Pl. 12.	Chaupi Orco, summit area.

Bratt (1960)

Pls. 30 and 34.	Azucarani, summit area.
Pls. 31 and 32.	Soral Este group.
Pl. 33.	Matchu Sochi Conchi, S side.

Melbourne (1960b)

P. 180.	Soral Oeste, summit; "Azucarani" Glacier; Soral Este.

Cordillera Real

Conway (1899b) [Photos taken in 1898.]

P. 19.	Illampu and Ancohuma, W side.
P. 21.	Caca Aca, distant.
P. 25.	Illimani.
Pp. 27 and 29.	Illimani, summit area.

_______ (1901) [Photos taken in 1898 and 1900.]

P. 132.	Glacier on Illimani.
P. 134.	Illimani, summit area.
Pp. 138 and 148.	Illimani.
P. 184.	"Huakana" Glacier.
P. 186.	"Huakana" Peak.
P. 234.	Ancohuma, summit area.

Hauthal (1911) [Photos taken in 1908.]

Pl. 40.	Illimani, W side.
Pls. 47 and 48.	Glaciers above Palca, in the Zora valley.
Pls. 51-53.	Illimani, W side.
Pl. 55.	Illimani, summit area.
Pl. 62.	Glaciers near Chacaltaya.
Pl. 64.	Caca Aca, SW side.
Pl. 65.	Caca Aca, NW side [excellent glacier termini].
Pl. 66	Caca Aca, summit area.

Dienst (1927)	
P. 97.	Caca Aca.
P. 98.	Illampu, summit; ice fall on Ancohuma.
Gerstmann (1928)	
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Pl. 31.	Chacaltaya.
Pl. 33.	Caca Aca [Huainapotosi].
Pfann (1929)	
P. 10.	Chaeroco to Chachacomani, panorama; Ancohuma massif [good glacier termini].
P. 12.	Calzada.
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________ (1929b)	
P. 39.	Illampu; Caca Aca.
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P. 329.	Ancohuma.
Pp. 336-337.	Caca Aca; unnamed peaks NW of Illampu and NE of Casiri.
Troll and Finsterwalder (1935)	
Pl. 24, Fig. 1.	Ancohuma massif.
Fig. 2.	Illampu massif, W side.
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Pizzotti (1936)	
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de la Motte (1940)	
P. 250.	Illimani, W side.
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Kühm (1941)
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Phillips (1943)
Pl. 8. — Illimani, distant.
Pl. 14. — Mururata and Illimani.

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Pl. 41. — Condoriri.

Hunter (1963)
Fig. 19. — Negruni range, from Chaeroco.
Fig. 20. — Chaeroco.

Cordillera Quimsa Cruz and Cordillera Santa Vera Cruz

Hoek (1905)
P. 172. — Cordillera Santa Vera Cruz.
P. 184. — Small glaciers in the Viloco valley, Cordillera Quimsa Cruz.

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Note: In Bolivia, according to Pan American Union (1964), aerial photographs of the Nudo de Apolobamba, Cordillera Real, and parts of the Cordillera Occidental were taken by the U. S. Army Air Force in 1942-44 and are now held by the U. S. Air Force. Since 1954 further aerial surveys have covered some mountain ranges; these photographs are held by the Instituto Geografico Militar in La Paz.

In Chile (Pan American Union, 1964), much of the country north of 43°S has been photographed from the air since 1955; most of these photographs are held by the Instituto Geográfico Militar in Santiago.

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Nordwestlicher Teil der Cordillera Real (Bolivien), 1:50,000. /Topographic map of the Illampu-Ancohuma-Casiri group surveyed in 1928, showing elevations of most glacier termini; published by Justus Perthes Gotha./

Echevarría (1959)
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Cordillera Real, Bolivian Andes, Based on works by the D. und O. A- V. 1928 Expedition with a Few Corrections and Additions by E. Echevarría 1958, 1:150,000 /scale has been reduced, in fact, to ca. 1:300,000/.

Hunter (1963)
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La Cordillera Real /ca. 1:35,000; E of Chaeroco, near 16°0'S, 68°20'W/

Cordillera Quimsa Cruz

Ahlfeld (1932)
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Karte der Cordillera Quimsa Cruz. /1:350,000/.

Prem (1945)
P. 325.

Sketch of Quimsa Cruz Range /1:400,000--bar scale length should be 10 km, not 40 km; a close copy of Ahlfeld, 1932, p. 83, but with some changed place names/.

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GLACIERS OF CHILE AND ARGENTINA BETWEEN LATITUDE 23°S AND LATITUDE 33°S

Between 23°S and about 30°S is a zone of extreme aridity where ice bodies exist under peculiar conditions, confined to peaks over 6000 m in elevation (Lliboutry, 1956, p. 305). Many but not all lie in shallow "cirques" or nivation hollows, and few have any crevasses or other signs of movement. They are formed from snow by refreezing and have no equilibrium line: the whole ice body has either a positive or negative budget, depending upon the year (Lliboutry and others, 1958, pp. 298-299). Pinnacles of ice or snow are almost universal (Lliboutry, and others, 1958, p. 296; Troll, 1942, pp. 47, 48, 62, and 63).

Between 23°S and 25°S the following peaks exceed 6000 m:

Peak	Altitude, m	Latitude S	Longitude W
Nevado de Chañi	ca. 6200	24°05'	65°45'
Cerro Pular	6225	24°15'	68°05'
Volcán Socompa	6050	24°23'	68°15'
Nevado de Acay	6340	24°25'	66°10'
Volcán Llullaillaco	6723	24°43'	68°33'
Nudos de Cachi	6550	24°50'	66°30'

The first peaks and also the last two, rise above the snowline; the other three also may because of their altitude, but the author has obtained no information.

The snowline on the Nevado de Chañi was 5800 m to 5900 m in 1901 according to Schmieder (1923, p. 142). A photograph of the summit in 1947 shows only a few snowbeds (Luscher, 1948, p. 111). In 1952 an expanse of smooth ice, probably permanent, was found between 5600 m and 6500 m on the west side of Llullaillaco; the absence of ice pinnacles was exceptional for this area (Lliboutry, 1956 p. 305; Lliboutry and others, 1958, p. 296). The Nudos de Cachi just reach the snowline and have a large permanent snowfield near the highest point (Boucher, 1949, p. 101).

Between 25°S and 27°S the following peaks exceed 6000 m:

Peak	Altitude, m	Latitude S	Longitude W
Sierra Nevada de Lagunas Bravas	6400	26°30'	68°37'
Volcán Antofalla	6440	25°35'	67°55'
Cerro Ermitaño	6187	26°46'	68°37'
Cerro Peña Blanca	6020	26°49'	68°40'
Nevado de San Francisco	6020	26°55'	68°18'

Eight separate ice bodies were recently found at about 5500 m on Cerro Peña Blanca (Lliboutry and others, 1958, p. 297). No information has been obtained about the other peaks.

Between 27°S and 29°S the following peaks exceed 6000 m:

Peak	Altitude, m	Latitude S	Longitude W
Nevado de Incaquasi	6610	27°03'	68°18'
Nevado El Fraile	6060	27°04'	68°23'
Nevado El Muerto	6470	27°04'	68°29'
Nevado Ojos del Salado	6880	27°06'	68°33'
Nevados de Tres Cruces	6330	27°05'	68°48'
Cerro Solo	6190	27°05'	68°43'
unnamed peak	6660	27°10'	68°40'
unnamed peak	6493	27°12'	68°40'
Cerro de Nacimiento	6493	27°17'	68°33'
Cerro de los Patos	6250	27°17'	68°50'
Cerro Azufre or Copiapo	6080	27°18'	69°08'
Cerro Pissis	6780	27°45'	68°50'
Cerro Bonete	6410	27°58'	68°40'
Sierra de Famatina or Sierra de Sangasta	6250	29°00'	67°50'

El Fraile has a permanent snow patch on the northwest side just beneath the summit, and El Muerto has two small "glaciers" on the south side almost completely debris-covered, but with firn pinnacles 5 m to 8 m high in places (Lliboutry and others, 1958, pp. 296 and 298).

The weather on Ojos del Salado is almost cloudless in winter but with constant high winds. Summer is cloudier (Carter, 1957, p. 78). The crater is full of ice and two glaciers lie on the mountainside, one below the other, the upper one heading in a cirque between 5900 m and 6400 m (Lliboutry, 1956, p. 306). According to Gajardo (1957, p. 89):

> The only two real glaciers on the mountain lie on this northwestern slope. Both end in tongues that descend to the northwest and northeast . . . The steeper lower glacier probably was once an extension of the upper one. The penitentes rose to as much as six feet above the surface of the glaciers. The snow-covered crevasses of the lower glacier required care . . .

Tres Cruces has a large embayment on its northeast side, in which five or six ice masses are separated by scree fans. Larger ice masses lie on the southern side (Lliboutry, 1956, p. 306). A comparison of photographs taken from Ojos del Salado in 1937 and 1956 shows no appreciable changes (Lliboutry and others, 1958, p. 298).

On Cerro Solo, a patch of snow or ice was seen below the summit in 1937 but in 1956 the mountain was bare. The unnamed summit of 6660 m probably has no ice cover (Lliboutry and others, 1958).

The Sierra de Anconquija [or Aconquija], reaching 5500 m, is considerably to the east of the main range and receives more precipitation. Half a century ago the permanent snowline was above 5000 m but below the summits which, however, carried no glaciers (Tapia, 1925, p. 316).

Cerro de Potro (28°25'S, 69°40'W) although only 5830 m in height, carries what Brackebusch (1892, p. 323) believed to be the most northerly glacier in the Argentine-Chilean Andes.

The Sierra de Famatina or Sierra de Sangasta (6200 m) apparently reaches slightly above the snowline but is without glaciers. Permanent snow is confined to gullies on a 5800 m peak but Cerro de la Mejicana (6200 m) is snow-capped, according to Bodenbender (1922, p. 21), whose estimate of the snowline (5500 m) appears to be too low. No information is available to the author about the other peaks.

South of about 29°S the northern limit of the zone of Mediterranean climate is reached, where winter cyclones bring considerable precipitation; as a result the firn limit falls from the very high levels of the arid zone to the north (Lliboutry, 1956, p. 306). The following peaks between 29°S and 31°S may have permanent snow or ice.

Peak	Altitude, m	Latitude S	Longitude W
Cerro del Toro	6380	29°08'	69°48'
Cerros Nevados [north of Paso del Chivato]	5458	29°25'	70°00'
Cerro Doña Ana	5690	29°45'	70°07'
Cerro de Las Tórtolas	6332	29°56'	69°54'
Cerro Olivares	6252	30°18'	69°55'

On or near Cerro Doña Ana, the firn limit in 1929 was about 5000 m and some glacier tongues reached 4150 m. In 1956 only small, stagnant ice bodies near 4800 m remained (Lliboutry, 1956, p. 306). Cerro de las Tórtolas has a glacier on its southeast side, starting 3 m below the summit and disappearing beneath debris at 5600 m (Lliboutry, 1956).

Between 31°S and 33°S the following mountains or mountain ranges are known to carry glaciers:

Peak	Altitude, m	Latitude S	Longitude W
Cordillera de Totora	5620	31°20'	70°10'
Cordillera de Ansilta	5800	31°30'	69°50'
Cerro Mercedario	6670	31°59'	70°07'
Cordillera de la Ramada	6410	32°05'	70°02'
Cerro Tambillo [or Cordillera del Tigre]		32°18'	69°39'
Aconcagua group	6960	32°40'	70°02'

The cordilleras of Totora and Ansilta, Argentina, are sometimes known as the Cordillera de San Juan (Kühn, 1927, Figs. 64 and 67). According to Heinsheimer (1949, p. 103), "the glaciers are small, situated at great altitudes, exposed to the evaporation and radiation of a very dry climate, hence very cold; therefore, they supply less water than, for instance, Alpine or Rocky Mountain glaciers of the same size would do." Floods occurred nearly every year in the first third of the nineteenth century, possibly connected with a glacier maximum. Ice pinnacles and ice walls between 10 m and 15 m high were found on Derecho Glacier, Cordillera de Totora (Heinsheimer, 1952). According to Sabor (1950, p. 111) the permanent snowline is at about 4200 m.

Photographs show that peaks to the north of Cerro Mercedario carry small glaciers (Daszynski, 1934, p. 218). On the north side of Mercedario is a large glacier of low gradient with few crevasses (Daszynski, 1934, p. 219). A photograph shows the southeast side of Mercedario to be almost completely ice-covered, with the ice forming a valley glacier at the base of the mountain (Daszynski, 1934, p. 217). Nine valley glaciers, some reaching from 8 km to 10 km in length, flow into the valley heading in the great semicircle of mountains from Mercedario to the Cordillera de la Ramada and facing northeast (Daszynski, 1934, p. 220). One of these may be the glacier that was noted earlier [probably in 1911], ending at 4000 m on Cerro Mesa (Kühn, 1918, p. 193). The Ramada group has flat-lying summit glaciers and steep icefalls leading to much more level glacier tongues below (Kühn, 1918, Pls. 8 and 9; 1927, Figs. 68 and 70).

In the Cordillera del Tigre in Argentina a large glacier lies on the northeast side of Cerro Tambillo, and two firn fields or small glaciers lie on the east and south sides (Magnani, 1949, p. 39). The permanent snowline in this area is at about 4600 m (Sabor, 1950, p. 111).

Aconcagua supports several valley glaciers but none reach the size of the larger Alpine glaciers (Reichert, 1915, p. 142). On the north and east sides are Güssfeldt, Vacas, and Relinchos glaciers. In 1896 a glacier-- probably Vacas Glacier--appears as a steep ice stream that just reaches the valley floor (Fitz Gerald, 1899, photo p. 38). The northwest face of the mountain itself carries very little ice (Reichert, 1910, p. 198; Kuhn, 1927, Fig. 63) and much debris falls onto Güssfeldt Glacier below. The glacier terminus was at about 4000 m in 1905-06 (Reichert, 1910, p. 199). On the south and west sides are Horcones Inferior and Horcones Superior glaciers (Jakob, 1940, p. 97). The Horcones Inferior is formed mainly by avalanching from the many hanging glaciers on the precipitous south face and is largely debris-covered (Fitz Gerald, 1899, p. 223).

On the south side of Cerro Tolosa, 12 km south of Aconcagua, Reichert (1910, p. 203) noted a small glacier whose tongue reached to about 5000 m and which still existed 40 years later (Emmons, 1945, p. 318).

The glaciers were in marked retreat in 1905-06 (Reichert, 1910, p. 203) and more recently Emmons (1945, p. 318) reported that they were still receding. He found a considerable body of stagnant glacier ice buried under debris; "it was apparently unconnected with its former source of supply, the Lower Horcones glacier, which has now retreated several miles to an altitude of about 13,000 ft. [4000 m]."

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Pp. 30, 114, and 224.	Aconcagua, S side.
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P. 143.	Cerro del Cuerno [NW part of Aconcagua group].
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Pp. 36, 38, 46, 54, 58, and 62.	Aconcagua.

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P. 263.	Tres Cruces.

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Eight photos of Aconcagua, S side.

Note: According to Pan American Union (1964), much of Chile north of 43°S has been photographed from the air since 1955. Most of these photographs are held by the Instituto Geográfico Militar in Santiago.

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GLACIERS OF CHILE AND ARGENTINA
BETWEEN LATITUDE 33°S AND LATITUDE 40°S

GLACIERS OF CHILE AND ARGENTINA BETWEEN LATITUDE 33°S AND LATITUDE 40°S

Immediately south of the trans-Andean railway, glaciers lie in the Nevado de la Plata in Argentina near 33°S, 69°25'W, and for about 270 km along and near the Chile-Argentina border from 32°55'S to about 35°20'S: the total area of ice is about 1270 sq. km (Lliboutry, 1956, pp. 307-309). Almost all the precipitation falls in the winter with westerly winds. The largest glaciers lie in Argentina on the leeward side of the mountain massifs, not only because of snow drifting, but also because the topography is less dissected than on the Chilean side. Another factor may be that the sun shines upon the eastern glaciers during the cooler half of the day, causing less ablation. As far south as 34°30'S there is as much ice in Argentina as in Chile (Lliboutry, 1956, p. 310).

Snow and ice pinnacles--nieve penitente--are more widespread and better developed in this region than anywhere in the world (Lliboutry, 1954, p. 465). The glaciers differ as much from glaciers in cool temperate regions as from those in the tropics and have been termed "subtropical" (Lliboutry, 1958, p. 265). Because precipitation is confined to winter, virtually all falls as snow on the glaciers (Troll, 1942, p. 46). Up to a very high altitude the entire winter snow accumulation is changed to ice by melting and refreezing during the dry summer, and permanent snowfields are thus very small or even absent. Superglacial ponds and water-filled crevasses show that the glaciers are below freezing point throughout the year [presumably at high altitudes]. In the ablation areas the glaciers carry little or no englacial or subglacial meltwater (Lliboutry, 1956, p. 312).

The equilibrium line is difficult to recognize on many glaciers for, in a wide zone of transition between the ablation and accumulation areas, the upper parts of the ice pinnacles may represent net accumulation while the hollows between represent net ablation (Lliboutry, 1954, p. 486). Temperatures at the equilibrium line are lower than those in the Alps: mean annual and summer temperatures in the Alps (Oberland) are 0°C and 3.5°C, respectively, and on Juncal Norte Glacier are -4.8°C, and -1°C (Lliboutry, 1956, p. 315).

In the southern part of the range, where winter precipitation is greater and the summers are less arid than in the north, the glaciers have more firn and less superimposed ice, and no pinnacles: they are more like those of the Alps. On the western side of the range the most northerly glacier of this type is at 34°40'S, but "subtropical" glaciers extend further south on the drier eastern side (Lliboutry, 1958, p. 265).

The mountains may be divided into ten groups [modified from Lliboutry, 1956, pp. 307-309].

Cordón del Plata

The Cordón del Plata [also referred to as Nevado de la Plata] extends for about 50 km northeastward, from about 33°10'S, 69°40'W, to about 32°45'S, 69°30'W. The maximum elevation has been variously given as over 5000 m (Caretta, 1945, p. 121); 5500 m (American Geographical Society 1:1,000,000 map, Sheet S.1.19); 5852 m (Chilean 1:250,000 map, Sheet 3370); or 6310 m (Bertone, 1937, p. 241). Glaciers are short and steep and covered with pinnacles. A long summit glacier trending north lies at 32°57'S, 69°26'W, on Cerro Rincón (Caretta, 1945, pp. 122-123).

Cerro Juncal Group
(32°55'S to Paso de las Pircas, 33°15'S)

The Cerro Juncal group contains Alto de los Leones (5445 m), Cerro Juncal (6060 m), Nevado del Plomo (6050 m), and several lower peaks. On the Chilean side the main glaciers are Juncal Norte and Escondido, flowing north, and Juncal Sur and Olivares Alpha, Beta, and Gamma, flowing south. These glaciers cover what is essentially a rectangular plateau 21 km by 8 km and trending northeast (Lliboutry, 1956, p. 323).

Juncal Norte Glacier is the only one that has a permanent firn field in dry years. Morphologically it is a valley glacier of classic alpine type, with an icefall connecting the steep, heavily crevassed accumulation area with a nearly level tongue. Below the icefall the spacing of Forbes bands suggests an annual velocity of 400 m. The position of the debris-free terminus changed little between 1942 and 1955, probably because the glacier's great range of altitude renders it rather insensitive to climatic fluctuations (Lliboutry, 1954, p. 486; 1956, p. 332).

Juncal Sur Glacier has its source on the south side of Cerro Juncal and is about 15 km long, the largest in Chile outside Patagonia. In 1947 it advanced some 3 km, pouring over an icefall at 3500 m and spreading out for 1 sq. km over the valley floor 600 m below (Lliboutry, 1956, p. 231). In 1950 the tongue was still crevassed and active, but by 1953 the crevasses had almost disappeared (Lliboutry, 1956, p. 331). Lliboutry (1956, p. 232) does not believe that the advance was caused by the avalanching of hanging glaciers, for the glacier consists of two branches, one of which had no hanging ice above it, yet both advanced. He attributes the advance to the heavy precipitation that is known to have fallen in the Santiago area in the period 1898-1905. Compared to its neighbors, the glacier is favored by having much of its accumulation area at a high level (Lliboutry, 1954, p. 493). Early in 1965 a group from the University of Chile studied the glacier. Movement was found to be very slow and there was evidence that the glacier, "composed of three ice streams, suffers perturbations in its mode of flow at the point of union" (Miller, 1965).

Olivares Alpha, Beta, and Gamma glaciers are of low slope, and lie mainly between 3800 m and 4600 m. The equilibrium line, taken as the level where moraines emerge from the ice, is at 4400 m, 300 m below the firn limit. In dry years, however, virtually no firn remains on the glaciers (Lliboutry, 1954, pp. 487-490). They are sensitive to climatic fluctuations because of their small altitude range, and a very clear vegetation trimline shows that they were formerly 100 m to 150 m thicker, and formed a single glacier. In 1935 Olivares Beta and Gamma glaciers were still joined, but from 1943 to 1953 Olivares Beta Glacier receded over a kilometer (Lliboutry, 1956, p. 324).

On the Argentine side Puente del Inca Glacier, flowing northeast from Cerro Tres Gemelos (32°52'S, 70°04'W), was 1 km to 2 km long and ended at 3900 m about 1906 (Reichert, 1910, p. 206). In the Río Blanco valley at this time were five glaciers between one and three kilometers long, all ending at about 3600 m; the longest was that flowing southeast from Cerro Tres Gemelos. An end moraine lay about 300 m lower and a kilometer in front of these glaciers (Reichert, 1910, p. 209). Forty years later the glaciers had disappeared except for some debris-covered ice (Domicelj, 1955, p. 229).

The topographic maps on a scale of 1:25,000 made by Helbling (1919) from a survey of 1908 are the best that have been made of the Santiago-Mendoza Andes (Lliboutry, 1954, p. 472). They cover the Argentine glaciers in and near the valley of the Río Plomo from 32°57'S to 33°14'S. Less accuracy is claimed for the sheet covering the glaciers on the northeast side of Tupungato. Helbling's glacier names differ slightly from those used by Lliboutry (1956) which are followed here.

In 1908 a terminal moraine lay about half a mile in front of the joint Juncal Segundo (Este) Glacier and Río Plomo Glacier (Larden, 1911, p. 226). Between 1908 and 1912 the glaciers slowly diminished and considerable changes in the distribution of clean and moraine-covered ice took place. By 1934 the glaciers had receded over 3 km and no longer joined (Helbling, 1935, pp. 45 and 47).

Nevado Glacier, which did not reach the valley floor between 1908 and 1912 (Helbling, 1935, p. 45), advanced 900 m between then and 1933 and dammed the Río Plomo. This became known in 1934 after the dam had broken and caused floods on the Río Mendoza. King (1934, p. 324) believed that the glacier advanced catastrophically during the year 1933, but Razza (1935, p. 222) saw no reason why it should not have advanced over a period of many years. He claimed that seven shore levels of the drained lake were annual, showing that the glacier had dammed the river in 1927. The hanging glaciers on Nevado del Plomo changed little between 1910 and 1934, but the wh... surface of the upper part of the main glacier sank (cf Helbling, 1935, Pl. 5, and King, 1934, Pl. 7).

Cerro de las Polleras Group
(Paso de las Pircas, 33°15'S, to
Paso del Tupungato, 33°18'S)

The Cerro de las Polleras group includes Cerro de las Polleras (5960 m), Cerro Chimbote (5683 m), and Sierra Bella (5340 m). In 1908 Reichert (1910, pp. 216 and 219) noted four glaciers, which he called Polleras I to IV. Polleras I on the northeast side was 3 km to 4 km long and ended at 3600 m, Polleras II on the eastern side was 6 km to 8 km long and also ended at 3600 m. Polleras III on the west side was a small ice body at about 4300 m, and Polleras IV on the south side was about 2 km long. All the glaciers were in retreat.

Tupungato Group
(Paso del Tupungato, 33°18'S, to
Paso Piuquenes, 33°38'S)

The Tupungato group includes Cerro Tupungato (6550 m), Nevado Piuquenes (6000 m), and Cerro San Juan. Four glaciers lie on the eastern side of Cerro Tupungato, according to Jakob (1940b, p. 97). Helbling (1919, p. 57) visited this side in 1912 and his map shows two small glaciers near the Paso del Tupungato and a larger glacier that flows northeast from the southeast side of the mountain and is composed of three branches. Photographs (Strasser, 1936, pp. 341 and 347) show the north side to be almost snow-free up to the summit and the west side to support a short, steep glacier. On the south side a glacier descends in a series of icefalls to the valley of the Río Tunuyán, the lower part hidden by debris. According to Jakob (1940a, p. 224) the glacier extends 7 km to 8 km beyond the icefalls, and on the map by Lliboutry (1956) it has a total length of about 18 km, all in Argentina.

Cerro San Juan is a volcanic cone with its crater filled with ice, and having several glaciers on its flanks (Jakob, 1940a, p. 220). A photograph shows a debris-covered ice tongue below an icefall (Jakob, 1940a, p. 221).

Southwest of the summit of Cerro Tupungato is the subsidiary crater of Volcán Tupungatito (5640 m). Lliboutry (1956) shows Tupungatito Glacier on its western side and Azufre Glacier on its southwestern side, both about 5 km long.

Southwest of Cerro San Juan a glacier that flows northwest and is the source of the Río Museo advanced rapidly for about 4 km in 1935 (Lliboutry, 1956, p. 231).

Cerro Marmolejo Group
(Paso Piuquenes, 33°38'S, to
Paso Nieves Negras, 33°52'S)

The Cerro Marmolejo group consists of the Cerro Marmolejo (6100 m) and the Volcán San José (5830 m) massif on the international border and a group of ice-covered summits to the west of the Portezuelo del Marmolejo. On Lliboutry's map (1956) the summit of Volcán San José is ice-free but glaciers descend from all sides of the massif. A glacier on the southwest side is said to have advanced 4 km to 5 km in 1927, reaching the exceptionally low altitude of 2680 m (Lliboutry, 1956, p. 231).

Cerro del Castillo Group
(Paso Nieves Negras, 33°52'S,
to Paso Maipo, 34°15'S)

The Cerro del Castillo group is dominated by Cerro del Castillo (5485 m) and Volcán Maipo (5290 m). According to Lliboutry's map, ice cover is restricted to small glaciers, mainly on the southern sides of the mountains.

Picos del Barroso Group
(Paso Maipo, 34°15'S, to
Paso Molina, 34°25'S)

The Picos del Barroso group is dominated by Picos del Barroso (5000 m) and Cerro Catedral (4770 m) [Pico de Padrones in Lliboutry, 1956]. Glaciers are mostly on the south sides of the peaks; the largest is Cachapoal on the south side of Picos del Barroso, reconstituted from a large hanging glacier and covered with debris (Lliboutry, 1956, p. 319).

Alto de los Arrieros - Cerro Sosneado Group
(Paso Molina, 34°25'S, to
Paso Las Damas, 34°53'S)

The Alto de los Arrieros-Cerro Sosneado group contains the Alto de los Arrieros massif (4986 m), Volcán Tinguiririca (4130 m) and the Sierras de Bellavista (4300 m) in Chile and some ice-bearing summits such as Cerro Sosneado (5189 m) and Volcán Overo (4619 m) in Argentina. The summers are less dry than in the latitude of Santiago and the most northerly glaciers of Alpine character are found with large firn areas, many crevasses and seracs, and abundant meltwater. They are found farther north in the wetter western part of the area than in the drier east. Ice or snow pinnacles are rare and are absent from the ablation areas, which can therefore be easily walked upon (Lliboutry, 1956, p. 336).

Several large glaciers flow from the Alto de los Arrieros-Cerro el Palomo massif. According to Lliboutry (1956, Fig. 50), Cortaderal Glacier flows east, Palomo Norte Glacier northeast, Cipreses Glacier northwest, and Universidad Glacier south. Photographs of Cipreses Glacier taken near the beginning of the century (Martin, 1909, Pls. 26 and 31) show a moderately steep valley glacier with its tongue covered with debris. Between 1957 and 1959 it receded greatly (Garcia, 1957, p. 125).

Universidad Glacier [also called Resurrección (Lankenau, 1958, p. 38) or San José (Echevarría, 1960)] is about 11.5 km long. It is composed of two branches, a west branch with a gently sloping accumulation area between 3500 m and 4300 m from which ice flows down a 600 m icefall, and an eastern branch with a lower accumulation area. In the summer of 1944-45, when the glacier was photographed during the aerial survey by the U.S. Army Air Force (Fl. 2, R 169-171), it ended in a highly crevassed lobe a short distance from an end moraine, which Lliboutry believed was evidence for a sudden and recent increase. By 1956 when the glacier was visited by a group from the University of Chile, the terminus had receded 1 km and the crevasses had mostly disappeared. Lliboutry (1958, pp. 262 and 264) believes the advance was caused ultimately by a series of very wet years that occurred from 1898 to 1905. Between 1905 and 1930 the glaciers in the vicinity had been receding (Lankenau, 1958, p. 38).

At the end of summer 1955-56, a normal year, the firn limit was about 3200 m on Universidad Glacier but no small glaciers in the area extended below 3500 m. This was the first difference noted between these glaciers and those near Santiago, where the firn limit was 200 m to 500 m above the smallest glaciers because of the role of refrozen meltwater (Lliboutry, 1958, p. 265).

The Volcán Tinguiririca massif (4130 m) has much more ice on the eastern side than on the western side; the climatic causes for this are uncertain (Viers, 1965, p. 100). Palacios Glacier, on the southeast side, ends at 2700 m (Lankenau, 1958, pp. 36 and 39). The snowline on the south side was at 2960 m at the end of summer (March) 1939, and an area that had been largely snow-covered in February 1861 was completely bare (Lankenau, 1958, pp. 23-24).

Aerial photographs taken in 1944-45 of the Sierras de Bellavista (34°35'S, 70°30'W) show a great number of small, steep glaciers, many with proglacial lakes (Fl. 2, V 167-171).

In Argentina Volcán Overo (4619 m; 34°34'S, 70°00'W) has a dome-shaped summit and typical volcanic cone glaciers, lying on the surface instead of occupying hollows (Kühn, 1925, p. 147). A glacier flowing south from the western crater has an accumulation area covered with ice pinnacles and contains no firn. Stakes placed across the glacier revealed a maximum annual velocity of 4 m (Colqui, 1961, quoted by Capitanelli, 1962, pp. 23-24).

Hauthal (1895, p. 112) found glaciers with wall-sided termini at the head of the Arroyo de las Lágrimas (about 34°45'S), a tributary of the Río Atuel. At 34°50'S, "Ventisquero del Humo" was over 4 km long and also ended in a vertical wall 10 m to 15 m high at 3800 m. All the glaciers in the area were receding, and some moraine-protected stranded ice lay about 500 m in front of the "Ventisquero del Humo." In 1912 Gerth (1926, p. 121) visited the upper valley of the Río Atuel. He found only one true valley glacier, 12 km long and occupying a right-hand tributary to the main valley, which it joined at 34°37'S, 70°08'W. The Río Atuel flowed beneath the ice tongue. Groeber found the ice bridge still in existence in 1914 but more recently [in the 1940's?], when he revisited the area, the glacier had receded 4.5 km. He estimated that over half a cubic kilometer of ice had disappeared, probably between 1920 and 1930 (Groeber, 1947, quoted by Capitanelli, 1962, p. 10). Other glaciers in the area have also receded greatly in recent years (Groeber, 1951, p. 348).

Volcán Peteroa Group
(Paso Las Damas, 34°53'S, to
Paso Deshecho, 35°18'S)

The Volcán Peteroa group contains Cerro Las Orejas (3960 m), Cerro El Horno, Cerro Santa Elena (3829 m), Volcán Planchón, and Volcán Peteroa along the international border, and several peaks with small glaciers to the east in Argentina.

About 1912 Cerro Las Orejas had small glaciers reaching 3200 m on both the Argentine and Chilean sides, and Cerro El Horno and Cerro Santa Elena also carried small glaciers on their western sides (Gerth, 1926, p. 121, and Pl. 7, Fig. 2). In the 1944-45 aerial photographs, however, the western sides of these last two peaks appear to be ice-free (Pl. 2, R 148). The eastern side of the range between Paso Las Damas and Cerro El Horno has extensive ice cover. Fairly clean, highly crevassed glaciers descend from icefields of gentle slope, the lowest reaching 2500 m. They have receded greatly in recent years (Viers, 1965, pp. 98-99).

Volcán Peteroa is an active volcano with a rounded, ice-covered summit and a crater surrounded by thick ice walls. Some snow or ice pinnacles develop (Gerth, 1937, Pls. 3 and 4), and at times the snow surface is black with ash (Pls. 5 and 6).

In Argentina several peaks west of the 70th meridian have small glaciers. About 1912 the firn limit on Los Dedos del Fraile (35°10'S, 70°10'W) and Cerro Risco Plateado (34°55'S, 70°00'W) was at 3600 m and 3800 m and the glaciers ended at 3550 m and 3600 m, respectively (Gerth, 1926, Pl. 6 and p. 121). In a recent aerial survey, no glaciers were

seen on Cerro Risco Plateado, but the eastern part of the massif was not seen. Twenty kilometers east of Cerro El Horno, seven cirque glaciers lie on the southeast side of a 4122-m-high ridge; the largest is 600 m long, and they appear to be on the verge of extinction (Viers, 1965, p. 101).

Nevados de Chillán-Volcán Lanín Group
(Paso Deshecho, 35°18'S, to Latitude 40°S)

Between Volcán Peteroa and 40°S only isolated summits carry glaciers. The U. S. Army Air Force aerial survey of 1944-45 (Fl. 2) photographed this area at the end of summer in 1945, and the photographs of Flight 2 clearly show the ice cover along the western side of the Cordillera.

Cerro Descabezado Chico (3250 m; 35°32'S, 70°37'W) has very small glaciers beneath its southeast ridge (Fl. 2, R 125).

Cerro San Francisquito (3480 m; 35°40'S, 70°24'W) has no glaciers but probably has some permanent snow (Fl. 2, R 118).

Cerro Campanario (4002 m; 35°55'S, 70°23'W) is a slightly dissected volcanic cone with a summit glacier and a small glacier on the southwest side (Fl. 2, R 98).

On a peak near 36°S, 71°10'W, are some short, highly crevassed glaciers (Fl. 2, R and V 92-94).

The Nevado de Lonquen (3230 m; 36°13'S, 71°10'W) is a moderately dissected volcanic cone with some ice bodies on and near the summit, especially on the southeast side (Fl. 2, R 83).

Volcán Domuyo (4785 m; 36°37'S, 70°27'W) lies in Argentina east of the main Cordillera. Photographs show small glaciers around the summit (Villaroel, 1950; and U.S. Army Air Force Fl. 2, R 71).

The Nevados de Chillán (3169 m; 36°52'S, 71°25'W) have a steep crevassed glacier on the southwest side flowing from the summit of the highest point, Cerro Blanco. A flattish icefield extends southeastward from Cerro Blanco to Volcán Nuevo (Fl. 2, R 50-53). A sketch map made in the middle of the nineteenth century (Philippi, 1863, Pl. 8) shows a broadly similar situation, but east of Volcán Viejo an extensive area of permanent snow and ice (Philippi, 1863, p. 246) had disappeared by the 1940's (Brüggen, 1948, p. 136).

Volcán Antuco (2985 m; 37°25'S, 71°20'W) is a fresh, undissected volcanic cone, bare on the western side but with ice on the south and east. Sierra Velluda nearby (3385 m; 37°28'S, 71°25'W) is a dissected

volcanic cone with some moderately long glaciers on the south side (Fl. 2, R 26).

Volcán Copahue (2969 m; 37°52'S, 71°10'W), Volcán Callaquén (3164 m 37°54'S, 71°25'W), and Volcán Lonquimay (2822 m; 38°22'S, 71°35'W) have ice-covered summits and typical volcanic cone glaciers on their flanks (Fl. 2, R 1 and 13).

Volcán Llaima (3124 m; 38°42'S, 71°42'W) and the very active Volcán Villarrica (2840 m; 39°25'S, 71°55'W) have glaciers.

Volcán Lanín (3776 m; 39°39'S, 71°30'W) is an extinct volcano. In 1896 Hauthal (1904, p. 53) found 3 km of completely debris-covered dead ice, forming the terminal part of a glacier on the north side. The accumulation area was small and the glacier shrank appreciably in the course of the next year. Continued great shrinkage took place from 1897 to 1909 and from 1909 to 1918 (Kühn, 1918, p. 177). A comparison of photographs from 1896 (Hauthal, 1904, p. 54) and 1933 (de la Motte, 1933, p. 328) shows no great shrinkage of the upper parts of the glacier. In 1933 the summit was a rounded dome of ice, estimated to be 45 m thick, with no trace of a crater. Ice extended 90 m down the northern slopes and 1200 m down the southern slopes (de la Motte, 1933, pp. 329 and 331).

Cerro Quetrupillán (2360 m), between Volcán Villarica and Volcán Lanín, may carry glaciers (see de la Motte, 1933, photo p. 329).

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P. 245.	"Vallecitos" Glacier; summit of "El Plata."
Caretta (1945)	
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Razza (1935)
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Marmillod (1940)

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Berge der Welt (1948)

Pl. 69.	Cerro Juncal.

Lliboutry (1954)

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_______ (1956) [Poorly reproduced photos.]

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Argentine Government (1900)

Pl. 40.	Cerro de las Polleras.

Reichert (1910)

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Strasser (1936)

P. 347.	Cerro de las Polleras.

Berge der Welt (1948)

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Fitz Gerald (1899)

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Jakob (1940a)	
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_______ (1940b)	
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Argentine Government (1900)	
Pl. 46.	Volcán Peteroa group.
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Pl. 7, Fig. 2.	Cerro Santa Elena and Cerro El Horno.

_______ (1937)	
Photos 1-6.	Volcán Peteroa.
U. S. Army Air Force (1944-45)	
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Lankenau (1958)	
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Nevados de Chillán-Volcán Lanín Group

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Hauthal (1904)	
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Kirchoff (1949)	
Pl. 188.	Volcán Copahue.
Pl. 195.	Volcán Lanín.
Villarcel (1950)	
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Note: In addition to the photographic sources listed above, references are given within the text to the U. S. Army Air Force 1944-45 aerial photographs.

According to Pan American Union (1964), much of Chile north of 43°S has been photographed from the air since 1955. Most of these photographs are held by the Instituto Geográfico Militar in Santiago.

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Pl. 6. *Der argentinische Anteil der Kordillere zwischen dem Rio Grande und dem Rio Diamante*, 1:200,000. [Published by Justes Perthes, Gotha.]

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Fig. 50. *Punzones-Palomo-Tinguiririca* [1:150,000].
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Viers (1965)
Fig. 5. *Glaciers quaternaires et glaciers actuels dans le haut bassin du Rio Grande* [1:475,000].
Fig. 7. *Glaciers et reliefs glaciaires entre le rio Tordil'o et l'Arroyo del Burro* [1:75,000].
Accompanying map. *Reliefs volcaniques et glaciers du massif du Tinguiririca (Chili central)* [1:28,500].
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GLACIERS OF CHILE AND ARGENTINA BETWEEN LATITUDE 40°S AND THE NORTH PATAGONIAN ICEFIELD (ABOUT 46°S)

GLACIERS OF CHILE AND ARGENTINA
BETWEEN LATITUDE 40°S AND THE NORTH
PATAGONIAN ICEFIELD (ABOUT 46°S)

South of the 40th parallel the Sierra de Lilpela (2290 m; 40°15'S, 71°47'W) had small glaciers along the crest at least as late as the end of the nineteenth century (Moreno, 1898, Pl. 36; Argentine Government, 1900, Pl. 55; Gallois, 1901, Pl. 14). Volcán Puyehue (2240 m; 40°35'S, 72°08'W) may support glaciers. In 1912 Cerro Puntiagudo (2490 m; 40°57'S, 72°15'W) had glaciers on the south side, but the north side had only snowbeds that Reichert believed probably disappeared in some years (Kölliker and others, 1917, p. 56). A photograph taken in 1937 shows the summit area thickly encrusted with ice (Henke and Hess, 1938, p. 590). Volcán Osorno (2660 m; 41°07'S, 72°30'W) carries glaciers and when Reichert climbed it, the ice and snow filling the crater formed a flat plain 300 m across. Fumaroles issued from rock outcrops around the rim (Kölliker and others, 1917, p. 59). Volcán Calbuco (2015 m; 41°20'S, 72°35'W) had a small glacier on its south side in 1912, and a large snowfield on the north side. The mountain erupted violently shortly after these observations (Kölliker and others, 1917, p. 66).

Cerro Tronador (3460 m; 41°10'S, 71°53'W) on the Chile-Argentina border is heavily ice-covered. The permanent snowline in the 1950's lay at 1500 m on the west side of Cerro Tronador and 1800 m on the east side (Lliboutry, 1956, p. 345), but in mid-February, 1963, it was at 2200 m on the southeast side (Flint and Fidalgo, 1964, p. 339). The summit is surrounded by a zone of steep crevassed ice with rock outcrops, below which is the gently sloping accumulation area. Surrounding this are steep cliffs down which ice avalanches or flows in icefalls. The continual avalanches have given the mountain its name, which means "Thunderer" (Jakob, 1936, p. 12).

The terminus of Frias Glacier on the northeast side of Cerro Tronador was 200 m wide and reached an altitude of 825 m at the turn of the century. In front were several regularly spaced recessional moraines. Casa Pangue Glacier on the north is a reconstituted glacier covered with debris on which shrubs grow. In 1911 it reached 370 m (Kölliker and others, 1917, p. 41) and has receded greatly since. On the southwest side of the mountain is Río Blanco Grande Glacier, whose debris-covered tongue reached 700 m (Lliboutry, 1956, p. 345).

On the southeast is Río Manso Glacier; its tongue is a reconstituted glacier 5 km long with a heavy debris cover (Lliboutry, 1956, p. 342). It is easily accessible and was studied in 1959. The results of this investigation showed that the glacier may have formed a massive end moraine about 2250 years ago and a much later readvance brought the glacier once

more up against this old moraine. A study of the growth layers of trees affected by this advance suggests that the glacier was in an expanded state from the early eighteenth century to 1795, from 1809 to 1821, from 1832 to 1834, and in 1847. Recently the central part of the terminus advanced a short distance into the forest dating from the mid-1920's; this advance was perhaps slowly continuing in 1959 (Lawrence and Lawrence, 1959, pp. 20-25).

According to Reichert, Cerro Techado (1880 m; 41°03'S, 72°05'W) had a small glacier on its southern side in 1910, and peaks near by of only 1400 m had small ice bodies (Kölliker and others, 1917, p. 49).

About 25 km east of Cerro Tronador, the mountains between Lago Nahuel Huapi and Lago Mascardi have small glaciers (Grüneisen, 1943). Flint and Fidalgo (1964, p. 339) reported that between 39°10'S and 41°20'S on the eastern side of the cordillera many empty cirques appeared to have lost their glaciers very recent[illegible] certainly in the last 200 years. All the cirque glaciers that they saw in this area were wholly below the firn limit in late February, 1963; one of the highest was situated at an altitude of 2000 m, 20 km southeast of Cerro Tronador [probably in the mountains between Lago Nahuel Huapi and Lago Mascardi where Grüneisen (1943) had noted several glaciers].

On Cerro Yate (2111 m; 41°45'S, 72°20'W) Reichert estimated the permanent snowline at 1200 m in 1912 but he gave the altitude of the termini of the western glacier as 1600 m and of the eastern glacier as 1500 m (Kölliker and others, 1917, p. 83).

Between Cerro Yate and 46°S most of the information about the glaciers comes from the 1944-45 aerial survey carried out for the Chilean Government by the United States Army Air Force. Unfortunately the flights were made early in the season when only the longest ice tongues reached below the snowline. Some of the Chilean 1:250,000 maps made from these photographs give a generalized picture of the ice cover, but others omit it altogether as Lliboutry (1956, p. 346) has noted.

The Cordón del Pico Alto (42°15'S, 72°10'W) has many short glaciers and at least one true valley glacier flowing northeast toward the Arroyo Ventisquero that has shrunk only slightly from a large end moraine. Some shorter glaciers flowing toward the Arroyo Alerzal have shrunk considerably from récent trimlines (Fl. 400, R 4-6). According to Rentzell (1935, p. 156), the mountains in the Cordón del Pico Alto have much larger glaciers than do mountains of the same height near Lago Nahuel Huapi.

Cerro Chato (2440 m; 42°30'S, 72°05'W) has several small glaciers much shrunken from recent trimlines (Fl. 400, R 16). In the 1870's the permanent snowline on the east side of Estero Comau at 42°25'S, 72°25'W, was at about 1300 m (Martin, 1880, p. 170).

Cerro Torrecillas (2133 m; 42°40'S, 71°55'W) has two cirque glaciers on its eastern side, the larger with an area of about 1.8 sq. km. This glacier is reconstituted beneath a 300-m cliff but only firn, not glacier ice, is said to avalanche down. The tongue was 600 m long and covered with debris in 1950 when the position of the terminus was marked. The firn limit, extrapolated from the tree line at 1300 m, has been estimated at 1500 m (Colqui and Madejski, 1952, pp. 211-214).

A photograph taken at the turn of the century (Krüger, 1900, Pl. 5) shows a glacier on the southeast side of Cerro Torrecillas ending a short distance from a grove of trees.

Volcán Minchinmávida (2470 m; 42°45'S, 72°25'W) is an almost completely ice-covered, little dissected cone (Fl. 400, R 34; Fl. 401, R 39). Krüger (1900, p. 15) noted two glacier tongues. The timberline in the vicinity he found to be at about 980 m, and the snowline at about 1410 m.

The entire area between about 43°S and Puerto Aisén at 45°20'S has far more glacier ice than the maps indicate. Huge avalanche cones and reconstituted glaciers are common. Volcán Corcovado (2300 m; 43°10'S, 72°45'W) has several glaciers (Fl. 401, L 188). Cerro Cuatro Pyrámides (2408 m; 43°08'S, 72°30'W) and Cerro Nevado (2042 m; 43°28'S, 72°50'W) are extensive rolling ice-covered plateaus, surrounded by precipices (Fl. 401, L 188). A glacier flowing toward the Corcovado valley reached 205 m above sea level at the turn of the century, according to Steffen (1919, p. 306; 1944, p. 286). A glacier forming the source of the Río Corcovado near 43°31'S, 72°24'W, terminated at 590 m in 1899. Its tongue was about 600 m broad and appeared to have been gradually retreating for some time (Krüger, 1909, p. 54). The mountains to the east along the Chile-Argentina border have many short, steep glaciers; the permanent snowline on the peak near 43°30'S, 71°40'W was at about 1700 m at the turn of the century (Krüger, 1900, p. 23).

Monte Melimoyu (2379 m; 44°05'S, 72°52'W) and Monte Macá (2960 m; 45°08'S, 73°15'W) are volcanic cones with extensive glaciers (Fl. 452, L 69; Fl. 401, L 125). An icefield of about 150 sq. km is centered on Cerro Overo (44°25'S, 72°25'W); the outlet glaciers have shrunk only slightly from end moraines (Fl. 401, L 145).

South of Puerto Aisén the ice as shown on the maps more nearly coincides with that visible in the aerial photographs. Between Puerto Aisén and the north Patagonian icefield are several mountain groups with short glaciers, and two small icefields. One icefield is at 45°55'S, 73°W. Short outlet glaciers on the east side all show signs of considerable recent recession (Fl. 406, L 202), but the 12-km-long Huemules Glacier flowing northwest has shrunk much less (Fl. 406, L 64). The other icefield at 46°08'S, 73°08'W also has a long outlet glacier flowing northwest that has shrunk little. All other glaciers in the area have receded

greatly from recent moraines. The permanent snowline between 45°S and 46°S on the west side of the cordillera is at about 1400 m (Sabor, 1950, p. 111).

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Pl. 36.	Cordillera de Lilpela [Ipela].
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Pl. 68.	Panorama N, W, and S from Cerro 30 de Marzo, 42°45'S, 72°10'W, including Volcán Minchinmávida.
Pl. 70.	Panorama S and W from Portezuelo Navarro, 42°43'S, 72°10'W.
P. 789.	Glaciers NW of Portezuelo La Cruz, 42°37'S, 72°07'W.
Gallois (1901)	
Pls. 17 and 18.	Cerro Tronador.
Pl. 21.	Panorama from Portezuelo Navarro [same as Argentine Government, 1900, Pl. 68].
Pl. 22.	Cerro Central group, 43°40'S, 71°35'W.
Pl. 25.	Glaciers on and near Cerro Ap Ywan, 46°10'S, 71°52'W.
Kölliker and others (1917)	
Pp. 42 and 46.	Cerro Tronador, summit area.
P. 52.	Cerro Techado, summit.
P. 52.	Cerro Puntiagudo, summit.
P. 54.	Cerro Puntiagudo.
P. 58.	Volcán Osorno, summit.
P. 82.	Ice on Volcán Calbuco before 1912 eruption; summit of Cerro Yate.
Steffen (1919)	
P. 136, Pl. 3.	Cerro Tronador, terminus of Frias Glacier.
P. 446, Pl. 25.	Glaciers on Nevado del Gallo.
Rentzell (1935)	
Pp. 157, 159, and 163.	Glaciers in the Cordón del Pico Alto.
Jakob (1936)	
Pls. 2-5.	Cerro Tronador.
Pl. 10.	Río Manso Glacier [?] on Cerro Tronador.
Pl. 14.	Río Blanco Glacier.

Henke and Hess (1938)	
P. 590.	Cerro Puntiagudo.
Palanza (1938)	
Pls. 31 and 33.	Cerro Tronador, Río Blanco Glacier.
Pls. 34 and 35.	Río Manso Glacier.
Grüneisen (1943)	
Pls. 66 and 70.	Glaciers between Lago Nahuel Huapi and Lago Mascardi.

U. S. Army Air Force (1944-45)
Details of aerial photographs are given in the text.

Berge der Welt (1948)	
Pl. 73.	Cerro Tronador.
Pl. 74.	Cerro Puntiagudo.
Pl. 75.	Volcán Osorno.

Note: According to Pan American Union (1964), much of Chile north of 43°S has been photographed from the air since 1955. Most of these photographs are held by the Instituto Geográfico Militar in Santiago.

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4573	Puero Aisén, 1953 (reprinted 1957).
4672	Lago Buenos Aires, 1953 (reprinted 1956).
4673	Monte San Valentín, 1950.

Lliboutry (1956)

Fig. 51.	Mapa Esquimético del Tronador [1:220,000].

GLACIERS OF CHILE AND ARGENTINA BETWEEN LATITUDE 46°S AND THE STRAITS OF MAGELLAN

GLACIERS OF CHILE AND ARGENTINA BETWEEN LATITUDE 46°S AND THE STRAITS OF MAGELLAN

The Andes between 46°S and the Straits of Magellan contain the two Patagonian icefields, the most extensive glacier systems in South America, resembling those of southeastern Alaska. The climate also is similar but even more maritime; summers are rather cooler with much stronger winds, and winters are warmer. One glacier from the northern icefield and many from the southern icefield reach sea level.

Bertone (1960) has listed 356 Argentine glaciers between 47°30'S and 51°S, giving the name, position, type, behavior, altitude of terminus, and area. Twenty-eight were stationary and the remainder receding. This publication should be consulted for such details on glaciers in this area.

Northern Patagonian Icefield

The northern Patagonian icefield has a maximum north-south length of 130 km and a maximum east-west width between glacier termini of 75 km. Much of the information presented here has been obtained from the aerial photographs taken for the Chilean Government by the United States Army Air Force in 1944-45. The glacier names follow Lliboutry (1956, Fig. 55), and unnamed glaciers are identified by the latitudes of their termini.

The icefield may be divided into a northern, a central, and a southern section. The northern section comprises the glaciers flowing from Monte San Valentín-- 4058 m on maps but probably 3876 m according to Lliboutry (1946, p. 360)-- and the entire basins of Circe, Pirámide, and Huata glaciers; it is rugged and very crevassed, with many nunataks (Fl. 406; R 90-94). The central section is an undulating, little-crevassed firn field (Reichert, 1923-24, p. 16), bounded on the south by a chain of mountains rising above it and extending southeastward from the south side of San Tadeo Glacier to the southern side of Colonia Glacier (Fl. 406; R 97-106). Its altitude is between 1100 m and 1500 m (Club Andino Bariloche, 1954, p. 3). Extensive snow morasses have been encountered in December at about 1100 m (Lliboutry, 1956, p. 360). The southern section includes the mountain chain and the icefield to the south. It is moderately rugged with many nunataks and crevasses (Fl. 406; R 114-124). In 1964 a party crossed this part of the icefield from San Rafael Glacier to Colonia Glacier and encountered several badly crevassed areas (Shipton, 1964, p. 186).

All the outlet glaciers on the eastern side of the icefield show signs of recent shrinkage. Those originating on and near Monte San Valentín, such as Circe and San Valentín Este, have a very heavy debris cover in

their lower portions and have shrunk vertically rather than horizontally (Fl. 406, L 86 and 178). Leones Glacier calves into a 10-km-long lake (Fl. 406, L 98): it is very rough and crevassed and a party attempting to go up it was forced to turn back (Joos, 1960). The end moraine enclosing the eastern end of this lake is 100 m to 140 m high and Heim (1940, p. 286) believed it was late-glacial in age. Nef, Colonia, and Pared Norte are long valley glaciers; the first two have shrunk moderately, the last has shrunk greatly from a recent maximum, as has neighboring Pared Sur Glacier (Fl. 406, L 109-124). All these glaciers carry much less debris than do those from Monte San Valentín.

East of the icefield several mountain groups are heavily ice-covered; all the glaciers show signs of great recent shrinkage. The Cordón Contreras (46°50'S, 73°W) is typical (Fl. 409, R 49-55).

On the western side of the icefield most of the glaciers are healthier than on the eastern side, and their surfaces are almost free of rock debris. Steffen Glacier has receded moderately (Fl. 558, V 10) and the glaciers at 47°20'S and 47°15'S have shrunk only slightly from recent end moraines (Fl. 558, L 17). The glacier at 47°13'S and Benito Glacier and its distributaries show little sign of shrinkage (Fl. 558, L 20 and 24, V 26). The mountains to the west of Steffen and Benito glaciers have many small glaciers not shown on the maps; they appear to have shrunk only slightly. The lobate terminus of San Tadeo Glacier has in places receded from an end moraine but elsewhere is against it. An older moraine lies beyond (Fl. 456, R 175; Fl. 555, L 27-30). Paulin (1933, p. 76), who traveled over San Tadeo Glacier in 1920, found the ice "even and of good quality over large areas" with little debris on it. He also noted the abundance of ice-dammed lakes in side valleys. The tongue of André Glacier, a distributary of San Tadeo Glacier, appears to have receded slightly since 1920, forming a small proglacial lake.

San Rafael Glacier is the only one from the northern icefield that has been investigated scientifically. It calves into a sea-level lake, reaching tidewater at a lower latitude than any other glacier in the world. Velocity measurements were made in 1921 (Reichert, 1923-24, p. 10) but the results are not known. The lake shore is formed by an end moraine; an older moraine lies a short distance beyond and a younger moraine, largely submerged, is between the lake shore and the ice front 10 km away. Muller (1959, p. 5) has called these the Tempanos I, II, and III moraines, in order of decreasing age.

Rhythmically bedded deposits (rhythmites), many of them probably formed in less than a year, suggest that the Tempanos I-II interval lasted 200 to 400 years or perhaps longer (Muller, 1959, p. 8). Organic material from near the base of bottom sediments of a pond on the Tempanos I moraine is 3610 ± 400 years old (Heusser, 1960, p. 568). Wood in peat 35 cm

beneath till near the present margin of the glacier is 6850 ± 200 years old; at that time the glacier was up-valley from its 1959 position (Heusser, 1960, p. 570).

From this evidence Heusser and Muller have reached different conclusions about the glacial history. Heusser (1960, p. 570), believes that the glacier advanced past its present position about 5000 years ago and reached its maximum at the Tempanos I moraine about 4000 years ago; later readvances formed the Tempanos II and III moraines. Muller, however, concludes that the till overlying the 6850-year-old peat near the present glacier margin is so unweathered that it must date from the historically documented advances of the glacier. The Tempanos glaciation, he believes, is late-glacial (Muller, 1960). Both Heusser and Muller admit difficulties in their interpretations: Heusser (1961, p. 15) is puzzled that the pollen record shows no glacial conditions compatible with the size and extent of the Tempanos moraines, and Muller (1960) is surprised that accumulation did not start earlier in the Tempanos I pond.

By A.D. 1675 San Rafael Glacier was probably again smaller than in 1959. In 1766 another advance was in progress, culminating shortly before 1882. Recessional moraines were formed about 1910 and 1935, and in 1958 the glacier was advancing into terrain that had been ice-free at least 29 years (Lawrence and Lawrence, 1959, pp. 13 and 18). In 1964 Shipton (1964, p. 186) reported that the glacier was still close to the forest. The whole surface was a chaotic mass of seracs and crevasses and the only route to the icefield was along the narrow trough between the forest and the glacier. In 1921 Reichert (1923-24, p. 10) noted that the lateral moraine was composed of uprooted tree-trunks; whether these dated from the 1882 maximum or the 1910 readvance is not known.

The joint glaciers Huata and Pirámide formerly extended into the Golfo Elefantes and formed moraines similar to those of San Rafael Glacier (Heusser, 1961, p. 5). Huata Glacier now shows no sign of shrinkage and may be advancing (Fl. 558, R 39, V 38). Pirámide Glacier has shrunk slightly.

A group of peaks reaching 1562 m between Pirámide Glacier and the coast carries small glaciers (Fl. 558, R 43) and at the northern end of the Península de Taitao at 46°S, 74°35'W, some peaks reaching 1312 m have small ice bodies near the summits (Fl. 456, L 16). The firn limit on the western side of the mountains between 46°S and 47°S may therefore be at about 1300 m, close to Sabor's estimate of 1320 m (1950, p. 111).

Glaciers Between Lago Buenos Aires and Lago San Martín

Lago Buenos Aires and Lago San Martín are on the eastern side of the Cordillera but drain into the Pacific by the Río Baker and the Río Pascua.

respectively. Many mountains with cirque and valley glaciers are situated between these two lakes and their river outlets.

On the southern side of Lago Buenos Aires near 46°45'S, 72°15'W, a group of cirque glaciers show signs of great recent shrinkage (Fl. 409, R 203).

Cerro Cochrane [or San Lorenzo] (about 3700 m; 47°35'S, 72°20'W) is heavily ice-covered with several valley glaciers radiating from the precipitous main peak. In 1940 the glacier on the northern side at the source of the Río Platten ended 200 m from a moraine-dammed lake into which it had been calving a few years previously (Agostini, 1941, p. 277). All the glaciers on Cerro Cochrane appear in the aerial photographs to have shrunk greatly from a recent maximum, though the lower parts of the two longest that flow west and south are completely covered by debris that has inhibited terminal recession (Fl. 409, R 175-178). A small glacier on Cerro Hermoso just east of Cerro Cochrane was reported by Magnani (1961, p. 10) to be against its terminal moraine.

West and southwest of the Cerro Cochrane massif are several small ice-covered plateaus from which short valley glaciers descend. These glaciers carry little debris in contrast to those on Cerro Cochrane, and all show signs of considerable recent shrinkage (Fl. 409, L 75-90).

The glaciers in the Gran Cordón Nevada (48°20'S, 72°45'W) have also shrunk considerably. The peninsula to the south, lying between the Brazo Norte Occidente and the Brazo Norte Oriente of Lago San Martín, contains many small glaciers, most of which have lost about a third of their length since a recent maximum (Fl. 409, L 110 and 145).

The Sierra de Sangra on the east side of the Brazo Norte Oriente is heavily ice-covered. Valley glaciers radiate in all directions from a central icefield and reach down to 1300 m (Bertone, 1960, p. 25). All have recently receded greatly and most now terminate in proglacial lakes. When a glacier flowing east toward the Río Mayer was photographed in 1897, it was considerably thinner than it had been at a recent maximum but had receded only a short distance from the end moraine (Hatcher, 1903, p. 142 and Pls. 16 and 17). By 1945 the glacier had receded an estimated 2 km to 3 km and a proglacial lake extended from the ice front to the end moraine (Fl. 409, R 150). Many cirque glaciers lie on the peaks due south of the Sierra de Sangra as far as about 48°50'S, their termini being at about 1400 m to 1500 m (Bertone, 1960, p. 29).

Southern Patagonian Icefield

The southern Patagonian icefield is 360 km long and extends through about three degrees of latitude from 48°15'S to 51°20'S. Its greatest

width between glacier termini is 90 km in latitude 48°50'S, but for much of its length it averages about 40 km. Outlet glaciers reach sea level in the fiords on the western side, many of which are choked with floating ice. On the east the largest glaciers calve into piedmont lakes at 185 m to 285 m above sea level. On the west coast the climate is extremely maritime: at Evangelistas (52°24'S, 75°06'W), for instance, slightly to the south of the icefield, average monthly temperatures range from 4.4°C to 8.7°C, and annual precipitation averages about 262 cm (Arroyo and Solar, 1958, pp. 20 and 27). By extrapolation Schwerdtfeger (1956, pp. 67 and 76) has estimated that on the icefield at 2000 m the average monthly temperatures range from -10°C to -5°C and the precipitation is 700 cm per year. Shipton (1962a, p. 124; 1963b, pp. 160-182), who spent several weeks in the accumulation area of the northern part of the icefield, has described the atrocious weather to be expected in midsummer, including heavy drifting blizzards with winds up to 200 km per hour. There is a great contrast between the warm northwesterlies and the cold southwesterlies; during a midsummer cold spell snow may on occasion lie at 500 m on the eastern side, 500 m to 600 m below the timber line. In these latitudes the winds are strongest and most persistent in summer (Lamb, 1959, p. 15), and in winter long calm periods are common.

Little scientific information is available about any of the glaciers and most travelers' information is about the more easily accessible eastern glaciers. The western glaciers and the higher parts of the icefield remained largely unknown till the 1944-45 aerial survey. A study of the aerial photographs shows that the western outlet glaciers and the small independent glaciers to the west of the icefield were then in a healthy condition, many of them being in contact with the forest; but on the eastern side, with few exceptions, the outlet glaciers had receded considerably from recent end moraines. Small independent glaciers to the east of the icefield had shrunk greatly, most having lost between a third and half of their former length.

The northern part of the icefield west of Lago San Martín is an extensive undulating plain with a few small nunataks (Fl. 556, L 126-140, R 65-75). Cerro Mellizo Sur and Cerro O'Higgins rise several hundred meters above the eastern side of the snow plain. Further south the icefield is much more rugged and crevassed and dominated by mountain peaks rising through it (Fl. 560, L 27-69).

An active volcano, Cerro Pirámide [or Lautaro] (3380 m; 49°03'S, 73°33'W), lies in the northern part of the icefield. Activity in recent years has been slight (Shipton, 1963b, p. 181) but, as evidence for past eruptions, large quantities of ash and pumice are reaching the surface in the ablation areas of glaciers within about 60 km of the crater. The volcano was first seen by Reichert in 1933 but Lliboutry (1957, p. 24), unaware of this, mistakenly located the volcanic center elsewhere (Shipton, 1960, p. 167).

Glaciers on the Western Side of the Icefield

Jorge Montt Glacier (Fl. 556, R 85) has receded considerably from a recent maximum--10 km in the last 40 years, according to Shipton (1963b, p. 117).

The two glaciers at 48°23'S and 48°25'S are in contact with the forest in places and close to it elsewhere (Fl. 556, L 91 and 98).

Bernardo Glacier is near a maximum (Fl. 556, L 98).

Tempano Glacier is in contact with the forest (Fl. 556, L 101).

The glacier at 48°50'S has receded slightly; layers of volcanic ash are melting out in the ablation area (Fl. 556, V 105, L 105).

Greve Glacier has much volcanic ash upon it. Part of the terminus appears to be advancing, and part has receded slightly (Lliboutry, 1957, Fig. 8; Fl. 560, R 6; Fl. 556, L 64 and 105). The glaciers on the west side of Cerro Pirámide are very steep and crevassed (Fl. 560, L 5).

South of Greve Glacier, Brüggen Glacier [or Pio XI] calves into Fiordo Eyre. In 1830 H.M.S. Beagle sailed to the head of this fiord and King (1839, p. 337) reported a river flowing through a lowland from a large glacier, presumably the Greve but possibly the Brüggen. He mentioned neither a tidewater glacier nor floating ice. In 1926 Brüggen Glacier advanced to the opposite side of the fiord (Agostini, 1941, p. 60); when and where this advance ended is not known, but by 1945 when the aerial survey was made the terminus was 3 km behind its 1926 position (Fl. 560, R 11, L 10; Fl. 556, L 56 and 113). In 1962 the terminus had readvanced about 5 km (Mercer, 1964). The glacier is very crevassed and many ice-dammed lakes occupy side valleys.

The glacier at 49°32'S is very crevassed and is near a maximum (Fl. 560, L 23).

On the eastern side of Fiordo Falcon the three glaciers at 49°32'S, 49°40'S, and 49°43'S, are near a maximum but the glaciers at the head of the fiord and along the western side have shrunk moderately from a recent maximum. They are all very steep and broken and apparently very active, for the fiord is choked with ice (Fl. 560, L 25).

Seno Penguin contains a great deal of floating ice but the calving glacier was hidden by cloud in the aerial photographs (Fl. 557, R 169). A calving glacier lies at the head of Seno Europa (Fl. 557, R 163), and Guillardi Glacier appears to be advancing (Fl. 557, R 159).

The glaciers on the western side of Seno Andrew have shrunk moderately from a recent maximum but on the eastern side and on the north side of the entrance to Fiordo Calvo are in contact with or near the forest (Fl. 560, L 42-45). These glaciers are all very steep and crevassed and carry little debris. Tilman (1957, p. 106ff) describes the difficulties encountered in ascending the glacier at 50°38'S, which he called "Calvo" Glacier. Of the lateral moraine he wrote, "compared with Himalayan moraines it was despicably small and failed miserably in offering the easy going that they generally provide. (The absence of well developed moraines was a characteristic of all the glaciers we saw.)" Further up they encountered a "frightful jumble of seracs and yawning chasms," and on the upper glacier they experienced extremely violent and unpredictable changes of weather.

Several steep, clean, and highly crevassed glaciers calve into Fiordo Calvo, producing large numbers of bergs. The recent behavior of the glaciers could not be determined from the aerial photographs (Fl. 560, L 49) but no marked recession is evident.

Asia Glacier is a clean, very crevassed tidewater glacier and is apparently advancing (Fl. 560, L 55).

Amalia Glacier is also a clean and very crevassed tidewater glacier. In the 1944-45 aerial photographs (Fl. 560, L 58, V 59) it had receded slightly from a recent maximum and was not far from where it had been in 1908 (Quensel, 1912, Pl. 4), but ten years later the terminus had apparently receded several kilometers (Tilman, 1957, p. 101, and Pl. 8a).

The three glaciers at 51°05'S, 51°08'S, and 51°11'S have shrunk moderately from a recent maximum (Fl. 560, L 63 and 64), and the glacier at 51°18'S is near a maximum (Fl. 410, L 133).

On the peninsulas and islands to the west of the icefield are some independent glaciers, few of which are shown on the maps. Glaciers recognizable on the photographs exist in the following places: Península San Martín, about 48°10'S, 74°10'W, highest point 1585 m (Fl. 456, R 131 and 556, L 91); Isla Serrano, 48°22'S, 74°45'W, highest point 1554 m (Fl. 456, R 67); North of Seno Tempano, 48°35'S, 79°15'W, highest point 1372 m (Fl. 456, R 119); Isla Wellington, at 49°S, 74°45'W (Fl. 456, L 83), and 49°20'S, 74°47'W, highest point 1311 m (Fl. 456, L 90); Península Exmouth, 49°25'S, 74°15'W (Fl. 456, R 96); between Fiordo Falcón and Seno Penguin, and between Seno Penguin and Fiordo Europa (Fl. 557, R 158-176).

These are mostly summit glaciers with small ice tongues descending from them, except between Fiordo Falcón and Seno Penguin, where several miniature icefields lie.

Glaciers on the Eastern Side of the Icefield

On the eastern side of the southern icefield and south of Lago Argentino four glaciers end in proglacial lakes with Pacific drainage; from south to north these are Balmaceda, Tyndall, Grey, and Dickson glaciers.

Balmaceda Glacier is about 12 km long, and is highly crevassed near its tongue (Fl. 410, R 129). Its lobate terminus dams three proglacial lakes (Fl. 411, R 37). Tyndall Glacier is about 35 km long, of gentle slope, and very clean; it dams two proglacial lakes, and shows signs of moderate recent shrinkage (Fl. 411, R 33). The tongue of 30-km-long Grey Glacier is split in two by a rock outcrop (Fl. 411, R 27). A comparison of photographs shows no obvious changes between the 1890's (Argentine Government, 1900, Pl. 134) and 1929 (Agostini, 1941, p. 103); both branches of the terminus reached the lake. According to local reports the glacier reached the forest in the mid-1920's but has been receding since (Lliboutry, 1956, p. 401). A conspicuous patch of surface moraine near the center moved down the glacier about 4 km between 1946 and 1956, an average of 400 m per year (Lliboutry, 1956, Fig. 59).

Dickson Glacier had receded moderately from a recent moraine when photographed in the 1890's (Gallois, 1901, Pl. 29). Nordenskjöld (1907, p. 32) described the calving terminus as low and the surface behind the terminus as very crevassed in 1896. Between then and 1943 photographs show that it receded an average of 17 m per year (Lliboutry, 1956, p. 401).

Small independent glaciers lie on the mountains to the east of the four glaciers just described. From Cerro Balmaceda (2035 m) two steep, clean glaciers descend to the shores of Seno Ultima Esperanza, separated from the water by end moraines. They show little change between 1908 (Quensel, 1912, Pls. 2 and 3), 1929 (Agostini, 1941, pp. 85 and 88), and 1945 (Fl. 411, R 39). The Cerro Paine massif has several short, rather dirty glaciers which showed signs of considerable recent recession when photographed, probably in 1929 (Agostini, 1941, pp. 90-107).

East of Cerro Balmaceda many small glaciers and glacier remnants lie on the mountains in the vicinity of Cerro Teneriel (1860 m), only a few of them shown on the Chilean 1:250,000 map. All show signs of great recent shrinkage of about a third to half their length and many no longer have any accumulation area (Fl. 411, V, L, and R 37-40).

The iceshed between the Pacific and Atlantic drainage separates Dickson Glacier from Frías Glacier, which flows toward the Brazo Sur of Lago Argentino. Frías Glacier was called "Richtergletscher" by Hauthal in 1899; the debris-covered glacier terminus was in retreat and 3 km of outwash lay between it and Laguna Frías, which was separated from Lago Argentino by some massive end moraines. These moraines, 7 km from the

present ice front, he believed to belong to the Late-Glacial. Three small ridges lay close to the ice tongue (Hauthal, 1904, pp. 45-46). Hauthal's account has been misinterpreted by Raffo, Colqui, and Madejski (1953, p. 339) to imply that the glacier at the end of the nineteenth century had receded 7 km from some very fresh moraines. Their error has been repeated by Lliboutry (1956, p. 401); in fact according to the map made from the 1945 aerial photographs, the width of the outwash plain and the distance of the glacier from the Brazo Sur are about the same as in 1899. The glacier terminates at about 280 m (Bertone, 1960, p. 102).

Moreno Glacier [Bismarckgletscher of Hauthal and Quensel] is a very clean glacier of about 200 sq. km that calves into Lago Argentino. It has become well known because it has consistently advanced since its discovery and in recent years has blocked an arm of the lake, causing severe flooding of grazing land. It has been under observation since 1899, when Hauthal surveyed the tongue; he repeated the survey the following year and found that the front had advanced. By 1908 Quensel found that it had advanced a further 100 m (Hauthal, 1904, p. 35; 1910, p. 139). In 1914 the glacier had advanced almost across the lake (Reichert, 1917, p. 229) but not till 1935 was the first ice dam formed. From 1935 to 1963 the glacier dammed the lake ten times and in October 1956, just before the dam broke, the water level had risen 23 m (Heinsheimer, 1956, 1958). The dam broke again in March 1963 when the writer was in the area. The glacier has been encroaching on forest hundreds of years old, according to Nichols and Miller (1952, p. 42).

Between 1947 and 1952 the Servicio Meteorológico Nacional studied Moreno Glacier. In 1948 they set out a line of stakes 5.5 km from the terminus, extending from the northern margin two thirds of the way across. Eighteen months later a resurvey of the stakes showed that annual movement increased from 35 m two hundred meters from the margin to 965 m in the central area (Raffo, Colqui, and Madejski, 1953, p. 328). The prime cause of the prolonged advance was believed to be the capture of part of the accumulation area of adjacent Frías Glacier which they believed [mistakenly as shown above] had receded 7 km in the late nineteenth century (Raffa, Colqui, and Madejski, 1953, p. 339).

Ameghino Glacier, about 15 km long and 52 sq. km in area, ends in a proglacial lake at 200 m above sea level, separated from Lago Argentino by an outwash plain. Studies of tree growth layers have shown that the glacier reached a maximum in the mid-1870's, since when it has shrunk 100 m to 150 m vertically. Parts of the margin were advancing in 1959 (Nichols and Miller, 1952, p. 46; Mercer, 1960, p. 2).

Mayo Glacier impounds a lake 6 km long, the western end of which is only 8 km from Seno Andrew, a branch of the Pacific, and several steep and narrow glaciers calve into this lake. The terminal area of Mayo Glacier

is very crevassed and almost impassable, and on the upper glacier there is an expanse of surface moraine formed by a huge landslide (Shipton, 1963b, pp. 52 and 58). The glacier has shrunk considerably from a maximum extent in the mid-1870's (Mercer, 1960, p. 3).

Spegazzini Glacier is a clean, very broken glacier that calves into Lago Argentino. The terminus changed little between the 1920's and 1959. A few very small glaciers lie in the Península Avellaneda to the east.

Onelli and Agassiz glaciers calve into Lago Onelli only a few meters above the level of Lago Argentino. Onelli Glacier has thinned moderately but has receded very little horizontally from a maximum that may have been reached in the 1880's. It descends in a series of icefalls from the divide but the lower part is little crevassed and is easy to travel on. The tongue appears inactive and produces few bergs. Agassiz Glacier is steep and crevassed and the tongue continually calves small bergs. In 1959 the margin was close to a trimline that had been formed in the mid-1870's (Mercer, 1960, p. 4).

Upsala Glacier is about 60 km long and has an area of 595 sq. km (Bertone, 1960, p. 78). Part of the terminus is a calving front about 2.5 km wide and part ends on land. Eight kilometers from the terminus the glacier is 14 km wide (Fl. 410, R 184). Very active and crevassed tributaries descend from the mountains on the west and compose about half the ice reaching the calving front. The other half comes from the undulating accumulation area near the head of the glacier.

The ablation area is moderately crevassed throughout but has been crossed on several occasions; for example, by Agostini in 1930 in order to reach the high snowfield overlooking Estero Falcón (Agostini, 1941, p. 151). The writer found traveling up the eastern margin of the glacier easy in late summer. Above the firn limit (about 1200 m in March 1958) skis could be used. The surface gradient was very gentle near the firn limit and the iceshed between Upsala and Viedma glaciers was only 200 m higher.

Radiocarbon dating has shown that Upsala Glacier was advancing about 350 B.C. and reached a maximum near 100 B.C. A later and less extensive advance culminated about A.D. 1600, when the calving front was about 8 km ahead of its present position. Most of the recession must have taken place before the present century, for a photograph by Skottsberg (1911, p. 274) shows the front close to its present position (Mercer, 1965, p. 408).

East of Upsala Glacier the higher pre-Cordillera carry many glaciers. A very steep glacier on the eastern side of Cerro Norte ends in a proglacial lake, round which are end moraines of two different ages, the older

formed about A.D. 350. On the southeastern side of Cerro Norte a reconstituted glacier also has two end moraines, the younger dating from about A.D. 1550 (Mercer, 1965, p. 409).

Southeast of Cerro Norte is a plateau glacier from which steep outlet glaciers descend to about 1000 m (Bertone, 1960, p. 65; Fl. 410, R 191).

Viedma Glacier is the only glacier that calves into Lago Viedma. A good account of two weeks traveling over the glacier near and above the snowline and the weather conditions encountered is given by Kölliker and others (1917, pp. 349-367). The glacier is composed of two branches of about equal size from the southwest and the north, separated by a large and conspicuous medial moraine. The total length of the glacier is about 40 km and its area about 575 sq. km (Bertone, 1960, p. 48). For about 8 km from the terminus the surface is impassable because of crevasses, but becomes smoother farther up. Much pumice and rust-colored ash comes to the surface in the ablation area. The nunatak in the middle of the glacier at the foot of the Cordón Mariano Moreno (Fl. 556, R 50; Fl. 410, R 206), from which the medial moraine starts, was believed by Lliboutry (1956, p. 413; 1957, p. 24) to be the volcanic source of the ash, but when the writer visited it in 1959 he found no trace of vulcanism; the active volcano, as has been mentioned earlier, is Cerro Pirámide. A large ice-dammed lake occupies the valley on the southern side of the glacier, mistakenly shown as a glacier on most maps. Two sets of stranded end moraines suggest that Viedma Glacier has varied in much the same way as Upsala Glacier.

Several independent glaciers lie in the mountains immediately east of Viedma Glacier, on Cerros Huemul and Solo, and the Fitz Roy group. The glacier on Cerro Huemul did not change perceptibly between 1916 (Kölliker and others, 1917, p. 336) and 1945 (Fl. 409, R 130). Two glaciers descend from the south side of Cerro Solor to the floor of the valley of the Río Túnel (Fl. 556, L 50), terminating at about 800 m (Bertone, 1960, p. 48). The western one was called De Quervain Glacier and the eastern one Túnel Glacier by Kölliker in 1917. Both glaciers had then receded from a recent moraine (Kölliker and others, 1917, Fig. 14). A photograph taken by the writer in 1959 shows little change.

In the valley of the Río Fitz Roy, Adela Glacier ends behind a proglacial lake (Fl. 556, L 47). It is a combination of several glaciers and the branch originating on the southern side of Cerro Fitz Roy carries much surface debris. The terminus has changed little since 1931 (Agostini, 1941, p. 211). Five end moraines lie in the valley and along the lake shore and, from a study of the vegetation, the dates of the two youngest have been estimated at pre-1900 and about A.D. 1700. From radiocarbon dating of a bog the third moraine is thought to date from about A.D. 1100. The two oldest moraines are of unknown age (Mercer, 1965).

Piedras Blancas Glacier, on the eastern side of Cerro Fitz Roy, ends in a proglacial lake surrounded by a massive end moraine that was breached by the lake in 1913 (Agostini, 1941, p. 218). No appreciable change in the glacier took place between 1937 (Agostini, 1941, p. 215) and 1945 (Fl. 409, R 127).

The glacier at the head of the Río Eléctrico valley is composed partly of ice from the eastern side of the Cordón Marconi and partly of ice from the main icefield. It offers easy access to the icefield and has been used by several parties. The tongue receded and the upper parts of the glacier thinned considerably between 1938 (Agostini, 1941, p. 229) and 1945 (Fl. 409, R 128; Fl. 556, L 44).

Five glaciers descend from the eastern side of the Cerro Gorra Blanca massif, all ending in proglacial lakes (Fl. 409, R 124).

Schönmeyer [or Chico] Glacier carries much volcanic ash. It calves into the head of the Brazo Sur of Lago San Martín: no changes in the position of the front were apparent between 1937 (Agostini, 1941, p. 254) and 1945 (Fl. 409, R 119; Fl. 556, L 37). All the many small independent glaciers on the high ground immediately east of Cerro Gorra Blanca and Schönmeyer Glacier have lost about a third of their length since a recent maximum (Fl. 409, R 120). Slightly farther east small glaciers on and near Cerro Bonnete (49°10'S, 72°55'W) have lost about half of their length (Fl. 409, L and R 123).

O'Higgins Glacier calves into Lago San Martín on a 6-km-wide front. It carries much volcanic ash. Its accumulation area has been estimated at 900 sq. km, lying between 1250 m and 1600 m. In January to February 1957 the temporary snowline was at 1080 m. In 1920 the terminus just reached a small island at the mouth of the inlet; by 1937 it had receded 800 m, by 1945 1700 m, and by 1957 6000 m (Corbella, 1957, p. 4). [The glacier in 1937 can be seen in Agostini, 1941, p. 240, and in 1945 in USAAF, Fl. 409, R 116; Fl. 556, L 34.] By 1960 Shipton (1960, p. 170) concluded from local reports that the terminus had receded 8 km since 1933 and the surface had lowered 180 m.

North of O'Higgins Glacier, Cerro O'Higgins (2773 m) and Cerro Melizo Sur (3292 m) rise above the icefield to the west. Most of the glaciers such as Oriental Glacier (Fl. 409, R 99) contain a component of ice from the icefield but consist largely of local ice. The large glacier southeast of Oriental Glacier, however, contains no ice from the icefield (Fl. 556, R 103). Many of these glaciers end in proglacial lakes.

Between Cerro Mellizo Sur and Brazo Norte Occidente of Lago San Martín are many small glaciers, not shown on maps, that have shrunk a third to a half from a recent maximum (Fl. 409, R 106-110).

Glaciers Between the Southern Patagonian Icefield and the Straits of Magellan

South of the southern Patagonian icefield the mountains along the western side of the Fiordo de las Montañas are heavily ice-covered and there is no icefree stretch around the head of the inlet, as is suggested on the maps (Fl. 410, L 120-126; Fl. 411, R 47). Five very steep and crevassed glaciers in the Cordón Sarmiento flow east and calve into the fiord; some have receded slightly, others moderately, from a recent maximum (Fl. 410, V 111-118). None of the glaciers on the western side reach the sea. Small glaciers not shown on the map lie along the crest of the high ground on the Península Roca on the eastern side of the Fiordo de las Montañas (Fl. 452, R 51; Fl. 410, V 124).

On the Península Antonio Varas between Seno Ultima Esperanza and Golfo Almirante Montt are many small glaciers, more than appear on the map. All show signs of recent shrinkage of a third to a half of their previous length and many no longer have accumulation areas (Fl. 411, L, V, and R 43-45).

Many glaciers lie in the southern part of the Península Muñoz Gamero, none marked on maps (Fl. 505, R 33). Shipton (1962b, p. 268) visited the area and noted a small icecap near the southern extremity. In the northwestern part of the peninsula, Monte Burney (1750 m) is heavily ice-covered (Shipton, 1963a, p. 233).

The island between the Península Muñoz Gamero and Isla Riesco has many glaciers and an icefield. The icefield, centered near 52°50'S, 73°10'W, is about 20 km by 10 km and rests on a plateau; no nunataks break the surface and the outlet glaciers are steep and clean. Slight recent shrinkage is apparent (Fl. 505, R 29).

The western half of Isla Riesco has many ice-covered peaks and mountain groups. A small icefield is centered on Cerro Ladrillero (1665 m); the outlet glaciers have recently receded slightly, and many end in proglacial lakes. On the southern side two reconstituted glaciers have a heavy debris cover but the other glaciers are clean (Fl. 505, R 19). Round Lago Riesco in the eastern half of Isla Riesco are many glacierets on hills up to 1040 m in height (Fl. 505, R 12).

In 1881 Coppinger (1883, p. 124) visited the glacier near the head of Bahía Ventisquero on the west coast of Península Cordova, the southwestern part of the Isla Riesco; it was then advancing into the forest and many dead trees were incorporated into its end moraine. By 1945 the glacier had shrunk moderately as had other glaciers in the peninsula (Fl. 505, V 91, L 89).

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Northern Patagonian Icefield

Reichert (1923-24)

Pls. 1, 2, 3, and 4.	San Rafael Glacier, 1921.

Pallin (1933)

Pp. 65 and 68.	San Tadeo Glacier.
P. 76.	Glacier in Seno Andrée.

Heim (1940)

Figs. 101 and 102.	Lago Leones and glaciers.

U. S. Army Air Force (1944-45)

Details of aerial photographs are given in the text.

Keller (1947-48)

Reproductions of twelve of the 1944-45 U. S. Army Air Force photographs of the northern icefield.

Berge der Welt (1948)

Pl. 77.	Monte San Valentín group, E side.
Pl. 78.	Upper Leones Glacier.
Pl. 79.	Part of northern icefield.

Lliboutry (1956)

Seven 1944-45 U. S. Army Air Force aerial photographs; poor reproductions.

Heusser (1960)

Fig. 2.	San Rafael Glacier, aerial view 1944-45.
Figs. 3, 4, and 5.	San Rafael Glacier, margin.

Shipton (1964)

Fig. 43.	On San Rafael Glacier.
Figs. 44 and 45.	On the northern icefield.

Glaciers Between Lago Buenos Aires and Lago San Martín

Hatcher (1903)

Fig. 16 and 17.	"Mayer" Glacier, headwaters of Río Mayer.

Agostini (1941)
Contains many photographs taken between 1913 and 1935, especially of the Argentine glaciers.

U. S. Army Air Force (1944-45)
Details of aerial photographs are given in the text.

Southern Patagonian Icefield

Agostini (1941)
Contains many photographs taken between 1913 and 1935, especially of the Argentine glaciers.

U. S. Army Air Force (1944-45)
Details of aerial photographs are given in the text.

Lliboutry (1956)
Six 1944-45 U. S. Army Air Force aerial photographs; poor reproductions.

Tilman (1957)

Pls. 11b, 12, and 13.	Icefield between Fiordo Calvo and Moreno Glacier.

Glaciers on the Western Side of the Icefield

Quensel (1910)	
Fig. 1.	Amalia Glacier, Seno Peel.
_______ (1912)	
Pl. 4.	Amalia Glacier, Seno Peel.
Lliboutry (1957)	
P. 19.	Greve Glacier; U. S. Army Air Force 1944-45 aerial photograph.
Tilman (1957)	
Pl. 8a.	Amalia Glacier [?] [reversed?].
Pls. 8b and 10.	Glacier on N side of entrance to Fiordo Calvo.
Shipton (1963b)	
P. 65.	Cerro Pirámide (Cerro Lautaro).

Glaciers on the Eastern Side of the Icefield

Argentine Government (1900)	
Pl. 132.	Head of Lago Rico, Lago Argentino.

P. 963.	Moreno Glacier terminus.
Pl. 133.	Laguna Frías and glaciers.
Pl. 134.	Grey Glacier.
Gallois (1901)	
Pl. 27.	Moreno Glacier terminus.
Pl. 29.	Stokes Glacier, Lago Dickson.
Hauthal (1904)	
Fig. 1.	Moreno Glacier, 1899.
P. 32.	Grey Glacier.
P. 48.	Laguna Frías; Stokes Glacier, Lago Dickson. [Etchings and paintings.]
_______ (1910)	
Fig. 3.	Moreno Glacier, 1899.
Fig. 6.	Moreno Glacier, 1900.
Fig. 7.	Moreno Glacier, 1908.
Quensel (1910)	
Fig. 8.	Upsala Glacier.
Skottsberg (1911)	
P. 274.	Moreno and Upsala glaciers.
Quensel (1912)	
Pls. 2 and 3.	Glaciers on Cerro Balmaceda.
Kölliker and others (1917)	
Pp. 114, 120, 122, 132, and 134.	Moreno Glacier.
Pp. 234, 256, 360, 362, 364, and 368.	Viedma Glacier.
Pp. 248, 264, 336, and 372.	Glacier on Cerro Huemul.
Pp. 250, 252, 262, 312, and 354.	De Quervain and Túnel glaciers, Lago Viedma.
Berge der Welt (1948)	
Pl. 74.	Moreno Glacier.
Pl. 80.	Glacier on E side of Cerro Fitz Roy.
Nichols and Miller (1952)	
Figs. 3, 4, 5, 7, and 10.	Moreno Glacier.

Lliboutry (1953a)	
P. 173.	Viedma Glacier; "Río Blanco" Glacier.
_______ (1953b)	
P. 257.	Cerro Fitz Roy and Adela Glacier, aerial view.
P. 258.	Piedras Blancas Glacier; Adela Glacier [Lliboutry's Grande Glacier].
Raffo and others (1953)	
Seventeen photos of Moreno Glacier.	
Lliboutry (1957)	
P. 18.	Viedma Glacier.
P. 19.	Glacier north of Viedma Glacier; U. S. Army Air Force 1944-45 aerial photograph.
Tilman (1957)	
Pls. 14 and 15.	Moreno Glacier.
Heinsheimer (1958)	
Figs. 1-12.	Moreno Glacier.
Shipton (1963b)	
Frontispiece.	Glacier near Lago Onelli.
P. 32.	Upsala Glacier.
P. 48.	Mayo Glacier.
Mercer (1965)	
P. 401.	Upsala Glacier, 1959.
P. 405.	"Dos Lagos" Glacier, 1964.

Glaciers Between the Southern Patagonian Icefield and the Straits of Magellan

Quensel (1910)	
Fig. 12.	Glacier in Canal Gajardo, Seno Skyring.
U. S. Army Air Force (1944-45)	
Details of aerial photographs are given in the text.	

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5173	Puerto Natales, 1953.
5273	Península Muñoz Gamero, 1954.
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Lliboutry (1953a)

Fig. 2.	*The South Patagonian Ice Field* [1:1,000,000].

_______ (1953b)

Fig. 1.	*The Monte Fitz Roy Region* [1:100,000].

_______ (1956)

Fig. 55.	*Hielo Patagónico Norte* [1:500,000].
Fig. 56.	*Hielo Patagónico Sur* (Parte Norte) [1:500,000].
Fig. 58.	*Hielo Patagónico Sur* (Parte Sur) [1:500,000].
Fig. 59.	*Paine* [1:150,000; shows Grey Glacier and Cerro Paine].

GLACIERS OF TIERRA DEL FUEGO

Tierra del Fuego comprises the archipelago south of the Straits of Magellan but the name is also applied to the main island of the group. Many glaciers lie in the mountainous belt running southeast from about 53°S in Isla Desolación to 55°30'S in Isla Hoste, the main concentration being in the Cordillera Darwin on the main island. Except for a few cirque glaciers in Argentina, all the glaciers are in Chile. Much of the information about the glaciers has been obtained from the aerial photographs taken in 1944-45 by the United States Army Air Force for the Chilean Government, and from reports of climbing expeditions, for few scientific observations have been made. Two Italian expeditions have included a glaciologist to make systematic field studies and the posthumously published work of de Gasperi (1922) remains by far the fullest written source of information on Fuegian glaciers; they are individually described and the positions of the termini marked on several sketch maps. In 1956 further observations were made on many of the same glaciers and the results are to be published in due course (Morandini, 1956 and 1957).

The Fuegian glaciers are on the whole very free from surface debris. Many of the longer outlet glaciers on the windward side of the range have suffered little recent recession and are close to the forest. Some of the glaciers that Conway (1899, p. 30) saw may have been advancing for he said that they "bulge at their snouts very differently from the glaciers of the Alps." Outlet glaciers of the leeward side of the range have mostly receded recently, and independent valley and cirque glaciers have shrunk considerably. According to Sabor (1950, p. 111) the permanent snowline is at 700 m on the west side of the mountains and 1000 m on the east.

On Isla Desolación an ice-covered massif is centered on Monte Hart Dyke (1097 m) at about 53°S and 74°W (Fl. 505, L 69).

The glaciers of Isla Santa Inés are the least known in southern South America, for clouds covered much of the island at the time of the aerial survey in 1944-45. An icefield covers most of the southeastern part of the island (Fl. 411, L 198). In 1964 an aerial reconnaissance was made of the northern and eastern parts of the island. Monte Wharton (1317 m) in the north had calving glaciers on both flanks, and two very crevassed and active glaciers calved into the head of Fiordo Helado in the southeast. Much of the icefield appeared suitable for travel on skis. The glaciers in the island did not appear to be shrinking (Miller, 1965, p. 26).

The higher parts of Isla Clarence and Isla Capitán Aracena support many cirque and ridge glaciers, which appear to have shrunk moderately (Fl. 411, L 212-222).

On the main island of Tierra del Fuego, a 10-km-long plateau glacier lies on the peninsula between Canal Gabriel and Seno Keats. In 1913, according to de Gasperi (1922, p. 255), some ice tongues descended to 150 m to 200 m above sea level, but for much of its length the margin was uniform and without glacier tongues. The 1944-45 aerial photographs show a similar situation (Fl. 411, R 143).

The Península Brecknock extends 90 km westward from Seno Contraalmirante Martínez. In the west, summits reach about 1000 m and carry small glaciers. The peaks are not very rugged and the glaciers are rather flat-lying (Fl. 412, R 28-36). The altitudes of the mountains and the extent of the ice cover increase progressively eastward, culminating in Monte Sarmiento (2300 m). Two very steep and broken glaciers that calve into Seno Chico have recently withdrawn moderate distances (Fl. 411, L 153). The peninsula between Seno Chico and Seno Negri is heavily ice-covered (Fl. 411, L 151).

Negri Glacier descends into the head of Seno Negri and is separated by a lagoon from a crescentic end moraine (Fl. 412, V 17; Fl. 411, L 149). In the early 1880's the glacier terminus was 40 m high and over 100 m from the shore of the lagoon, and Bove (1883, pp. 101-102) concluded that it was retreating rapidly. In 1913 de Gasperi (1922, p. 265) estimated the terminus to be about 100 m from the low, comparatively recent end moraine along the lagoon shore; a much older and more massive end moraine lay beyond (de Gasperi, 1922, p. 237). Aerial photographs cannot easily be compared with those taken from the ground but no change in the position of the terminus is evident between 1913 and 1945 (Fl. 412, V 17).

Glaciers flow in all directions from Monte Sarmiento (2300 m), whose summit, like all the higher mountains of Tierra del Fuego, is encrusted with ice and rime. Several expeditions have climbed on the mountain. According to Conway (1902, p. 196) the glaciers on the western side reached the water when H.M.S. Beagle was there about 1830 but 70 years later had receded behind densely wooded moraines. However, these moraines not only supported fully grown trees, but were covered by a thick layer of rotting timber, so the Beagle's interpretation may have been wrong. The 1944-45 aerial photographs do not show any great recent shrinkage (Fl. 411, L and R 147). Agostini (1959, p. 74) referred to the northern glacier as Schiaparelli, and the southern as Conway. His Lovisato Glacier on the southwest side is the only one with much debris cover.

In 1956 an Italian expedition climbed Monte Sarmiento from the east. Out of 57 days spent in their base camp on the water's edge, only five were rainless. The average daily rainfall was 12 mm which, if maintained, would be over 400 cm a year. The permanent snowline lay at 600 m (Agostini, 1959, pp. 16 and 118). Near the base camp were Blanca Glacier that was about 50 m thinner than in 1910 and Emma Glacier that had changed little (Morandini, 1956, pp. 2963 and 2972). These and other glaciers on the

western side of Seno Contraalmirante Martínez carry little surface debris (Fl. 411, R 143; Fl. 412, R 11).

The peninsula between Seno Contraalmirante Martínez and Seno Agostini is heavily ice-covered. Several glaciers flow toward the first inlet but do not reach the water; they appear to have receded moderately (Fl. 412, L 9, R 11). Several glaciers calve into Seno Agostini and the positions of their termini in 1913 are shown by de Gasperi (1922, Pl. 15). In the 1944-45 aerial photographs little change is evident except that the glacier at 54°29'S, 70°27'W (de Gasperi's "fourth" glacier) has receded considerably (Fl. 411, L 138; Fl. 412, L, V, and R 7). All the glaciers are very steep and crevassed. The calving glacier at the head of Seno Serrano, the southern branch of Seno Agostini, carries much debris on its surface (Fl. 412, L 1). The glacier at the head of Seno Hyatt, the northern branch of the Seno Agostini, produces many more bergs than do the other calving glaciers (Fl. 410, L 93).

On the northeast side of the entrance to Seno Agostini are several small glaciers that reminded de Gasperi (1922, p. 252) of those in the Dolomites. Considerably recent shrinkage is evident in the 1944-45 aerial photographs (Fl. 412, R 3).

Glaciers between Seno Agostini and Bahía Filton are clean, steep, and very crevassed, and show signs of slight to moderate recession. The large glacier flowing toward the head of Bahía Filton is near a maximum position (Fl. 410, L 89). The small cirque glaciers between Bahía Filton and Bahía Brooks show signs of considerable recession (Fl. 410, L 86).

A large glacier calves into an inlet on the west side of Bahía Brooks at 54°31'S (Fl. 410, L 83). The inlet divides into two in its upper part, and the steep glacier calving into the head of the western branch was called Finlandia Glacier by the 1928-29 Finnish Expedition (Kranck, 1932, p. 75). It is clean on its eastern side but dirty on its western side. Between 1929 and 1962 the glacier receded, exposing a large area of rock at the terminus (cf Kranck, 1932, Fig. 22; Shipton, 1963b, p. 193). To the west of Finlandia Glacier, Shipton (1962, pp. 261-264) noted a lagoon into which three large glaciers calved. From there he crossed to Bahía Pía, Beagle Channel, and back, experiencing very changeable weather with gales and heavy snowfall.

Marinelli Glacier that calves into Bahía Ainsworth is 25 km long and has a 5-km-wide front (Agostini, 1959, p. 33). Apart from two conspicuous medial moraines the surface is clean. In the upper part of the glacier, Shipton (1962, p. 265) found enormous transverse crevasses. Some moderate recent recession is evident in the 1944-45 aerial photographs (Fl. 410, L 78), but the terminus is in much the same position as in 1913 (Gasperi, 1922, Pl. 17).

Several glaciers calve into Bahía Parry. Della Vedova Glacier is separated from the southeastern branch of the bay by a 3-km-wide outwash plain. The gradient is low and the glacier carries a considerable amount of surface debris on its eastern part. In 1913 the terminus had receded from a recent trimline (Agostini, 1929, p. 112) and in 1945 was in much the same position (Fl. 410, L 70).

East of Bahía Parry the continuous ice cover of the Cordillera Darwin ends and the mountains become progressively lower, supporting short valley glaciers in the west and small cirque glaciers in the east. Small glaciers lie behind Ushuaia, the easternmost about 25 km east of the town (Fl. 507, L 50-54). In the 1890's they ended at about 700 m (Nordenskjöld, 1907, p. 29). They are the only glaciers in Argentine Tierra del Fuego.

The peninsula between Lago Roca and Bahía Yendegaia contains small glaciers, some of which were entirely below the firn limit in 1945 (Fl. 507, L 40). The peninsula between Bahía Yendegaia and the Beagle Channel also contains small glaciers with no accumulation areas, and larger ones with signs of considerable recent shrinkage (Fl 507, L 36-38).

Steppani Glacier flowing toward Bahía Yendegaia ends 10 km from the sea, further than any other outlet glacier in the Cordillera Darwin. Hyades (1887, p. 150) described it as descending in two or three great steps. The lower part is of low gradient and carries some surface debris. The terminus appeared to be receding in 1929 (Kranck, 1932, Fig. 40) and little change was evident in 1945 (Fl. 507, L 35).

In 1883 a photograph that is probably of Francés Glacier seems to show active ice at the terminus advancing over dead ice (Hyades, 1887, Pl. 5). The photograph was described as showing a well-vegetated moraine 60 m high with a 50-m wall of ice on its crest (Hyades, 1887, p. 485). In 1913 the glacier ended about 20 m above sea level, and was about 750 m wide at the terminus (Gasperi, 1922, p. 229). It descends in a tremendous icefall and in 1945 was very close to a maximum position (Fl. 507, V 32). Shipton (1963a, p. 235), when climbing Cerro Bove at the head of Francés Glacier, noted the "remarkable absence of névé even in the highest glacier basins." On the summit ridge he encountered "a mounting series of huge ice bosses like gigantic cauliflowers poised on a narrow crest, overhanging on either side."

Between Francés Glacier and Italia Glacier the small independent glaciers showed signs of considerable recent shrinkage in 1944-45 (Fl. 507, L 32-33).

Italia Glacier descends in a wide icefall that narrows rapidly toward the calving terminus at the head of a small bay. Agostini (1959, p. 163) noted that the terminus had advanced about 1 km after 1914, destroying

vegetation, and had then receded to its previous position by 1956 (cf Agostini, 1929, p. 161; 1959, p. 149). This advance must have culminated near 1945 for the aerial photographs taken then show the terminus protruding into the Beagle Channel (Fl. 507, V 30).

Roncagli Glacier was described in 1913 as a typical alpine glacier, terminating a few meters above sea level but several hundred meters from the sea (Gasperi, 1922, p. 230). In 1944-45 it appeared to be starting to recede from a maximum position. Two lakes are dammed in side valleys on the west side; the terminus of the glacier at the head of the southern lake is completely hidden by debris and a glacier on the north side of the northern lake is in a similar state.

In 1959 the main part of Romanche Glacier ended a considerable distance above sea level and a large waterfall issued from it. A narrow tongue of ice on the eastern side reached the water (photo by E. Godley, on file in The American Geographical Society). Descriptions of the glacier in 1883 (Hyades, 1887, p. 151) and 1913 (Gasperi, 1922, p. 231), and photographs from 1896 (Nordenskjöld, 1907, Fig. 3), probably 1913 (Agostini, 1929, p. 167), and the 1944-45 aerial photographs (Fl. 507, L 25) show a similar state of affairs.

Bahía Pía is a narrow fiord about 15 km long with two branches; about six glaciers reach the water (Fl. 507, L 22).

Oblicuo Glacier, east of Seno Garibaldi, appeared to be near a maximum in 1944-45 (Fl. 507, L 19).

Seno Garibaldi (Fl. 507, L 16) and Seno Ventisquero (Fl. 412, L 112) have calving glaciers at their heads. Arctowski (1908, p. 16) visited Seno Ventisquero in 1897 and noted that the glacier was of low gradient and extremely crevassed.

The glaciers between Seno Ventisquero and Bahía Océano have recently suffered slight to moderate recession (Fl. 412, L 107).

South of the main island of Tierra del Fuego small glaciers exist in islas Stewart, Londonderry, and Gordon, and more extensive glaciers on Isla Hoste. Isla Stewart has a few very small ice bodies near its highest point of 860 m (Fl. 412, R 86). Isla Londonderry has a group of rather flat-lying glaciers on its western peninsula, probably about 3 km in length (Fl. 506, L 94; Fl. 412, R 97). In 1913 de Gasperi (1922, p. 233) estimated that their tongues reached 400 m to 500 m above sea level. Isla Gordon, reaching 975 m, has many short valley glaciers; most did not reach below 600 m in 1913, according to de Gasperi (1922, p. 233), but one extended to about 200 m. In the 1944-45 aerial photographs all the glaciers appeared to have suffered slight to moderate shrinkage (Fl. 507, R 25).

The Península Cloué in the western part of the Isla Hoste has an icefield about 20 km across, which was visited by the French *Romanche* Expedition in 1883. They called the glacier on the north side, flowing down to the Beagle Channel, Des Moines Glacier for its profile resembled a row of monks reading their breviaries (Hyades, 1887, p. 151). At the end of the Estero Fouqué they ascended Fouqué Glacier onto the icefield. Hyades considered it to be one of the most curious glaciers of the Beagle Channel; its margin formed a steep cliff 10 m to 15 m high, and where it reached the sea it was narrow (200 m) and high (40 m to 50 m) and constantly calving small bergs. The 1944-45 aerial photographs show that several long rock ridges break the surface of the icefield. Some outlet glaciers, including Fouqué, are near a maximum and others have receded slightly (Fl. 507, R 22 and 90; Fl. 506, L 118).

Glaciers are scattered throughout the rest of Isla Hoste; all are small and all are receding. In the Península Dumas, which reaches 1097 m, and in the Península Pasteur some of the smaller glaciers were entirely below the firn limit in 1944-45 (Fl. 507, R 34-44, L 66). Small shrinking glaciers also lie in the Península Rous (Fl. 507, L 86) and the Península Hardy, these being southernmost in South America (Fl. 507, L 67; Fl. 506, R 42).

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Hyades (1887)	
Pl. 13.	Glacier in Estero Webb, Isla Hoste.
Pl. 14.	Part of Fouqué Glacier, Isla Hoste.
Martial (1888)	
Pl. 2.	Isla Gordon, Bahía Romanche [small glaciers].
Pl. 5.	"Glaciar de Mont Darwin" [Francés Glacier?]
Conway (1902)	
Pp. 194 and 196.	Monte Sarmiento, glaciers on W side.
Nordenskjöld (1907)	
Fig. 2.	Glacier in Estero Webb, Isla Hoste [same as Hyades, 1887, Pl. 13].
Fig. 3.	Romanche Glacier.
Arctowski (1908)	
Pl. 1.	Glaciers behind Ushuaia; glacier in Seno Ventisquero.
Gasperi (1922)	
Pl. 9.	Italia Glacier.
Pl. 13.	Negri Glacier.
Pl. 16.	Icefield between Canal Gabriel and Seno Keats.
Pl. 18.	Front of Marinelli Glacier.
Pl. 19.	Monte Sarmiento, glaciers on SE side.
Agostini (1929)	
Pp. 35, 160, and 170.	Italia Glacier.
Pp. 53, 58, and 80.	Monte Sarmiento, glaciers on W side.
Pp. 56, 64, 66, 67, 69, 70, and 89.	Schiaparelli Glacier.
Pp. 61, 62, and 63.	Negri Glacier.
Pp. 88, 96, 105, 107, and 108.	Marinelli Glacier.
Pp. 90 and 95.	Seno Agostini.
P. 92.	Glacier in Seno Contraalmirante Martínez.
Pp. 104 and 112.	Glaciers in Bahía Parry.
Pp. 140, 146, 147, 149, and 150.	Glacier near Ushuaia.

P. 163.	Roncagli Glacier.
P. 167.	Romanche Glacier.

Plüschow (1929)

P. 112.	Seno Agostini, unnamed glacier terminus.
P. 114.	Seno Agostini, two glaciers.
P. 145.	Seno Agostini, W side, aerial view.
P. 192.	Roncagli Glacier and ice-dammed lake.
P. 257.	Seno Serrano, glaciers at entrance.

Kranck (1932)

Figs. 22, 23, 25, 27, and 30.	Glaciers at head of Bahía Brooks.
Fig. 40.	Steppani Glacier.

Agostini (1955) [Some are the same as Agostini, 1929.]

P. 26.	Monte Sarmiento, W side.
Pp. 34 and 36.	Schiaparelli Glacier.
P. 53.	Negri Glacier.
P. 54.	Icefield between Canal Gabriel and Seno Keats.
Pp. 62 and 63.	Seno Agostini [same as Plüschow, 1929].
Pp. 80 and 99.	Marinelli Glacier.
Pp. 81, 89, and 98.	Bahía Parry.
P. 143.	Oblicuo Glacier.
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P. 153.	Italia and Francés glaciers.

_______ (1959)

P. 12	Roncagli Glacier.
Pp. 40, 43, 80, 90, 94, 97, and 98.	Blanca Glacier.
P. 108.	Glacier in Bahía Escandallo [Seno Contraalmirante Martinez].
P. 122.	Emma Glacier.
P. 149.	Italia Glacier.
P. 168.	Francés Glacier.
P. 174.	Roncagli Glacier, W side.
P. 188.	Monte Sarmiento, "cauliflower" ice formation.

Shipton (1962)

P. 262.	Marinelli Glacier.

_______ (1963b)

P. 193.	Glacier at head of Bahía Brooks.

P. 208.	"Cauliflower" ice formation on Cordillera Darwin.
Miller (1965) Pp. 23 and 25.	Glaciers in SE Isla Santa Inés.

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Gasperi (1922) [Based on British Admiralty charts and information about glacier termini obtained in 1913.]

Pl. 10.	Le fronti dei principali ghiacciai del Canale Beagle, 1:150,000.
Pl. 11.	Fiord Negri: Ghiacciaio e Lago Negri, 1:75,000.
Pl. 14.	Gruppo del Sarmiento, 1:150,000.
Pl. 15.	Nuovi Canali in Fonda al Seno Keats nel Canale Magdalena, 1:150,000.
Pl. 17.	Ghiacciaio della Baia Ainsworth [G. Marinelli], 1:25,000.

Agostini (1959) [Contour and shaded relief maps.]

P. 74.	Monte Sarmiento [1:200,000].
P. 116.	Monte Sarmiento [1:36,500].
P. 152.	Monte Italia [1:160,000].

GLACIERS OF EAST AFRICA

Mount Kenya, the Kibo summit of Kilimanjaro, and a group of six mountains in the Ruwenzori carry glaciers; although the latter are just north of the equator, they are included here because they are closely related geographically.

Mount Kenya
(5199 m; 0°10'S, 37°10'E)

Mount Kenya is a highly eroded extinct volcano that was probably active in the late Tertiary. It is a broad dome about 90 km in diameter, from near the center of which rises a rugged mass culminating in the twin peaks Batian, 5199 m, and Nelion, 5188 m (Light, 1941, Pl. 181). In the immediate vicinity of these peaks are twelve small glaciers, totaling 1.2 sq. km in area; seven glaciers occupy valleys or depressions and five are hanging glaciers (Charnley, 1959, p. 483).

Gregory visited the mountain in 1893 and made some observations on the moraines. Near Lewis Glacier, the largest, he noted five small, closely spaced end moraines, the innermost of which was being breached by a slight readvance of the glacier (Gregory, 1894a, p. 98; 1894b, p. 521; 1894c, p. 420). Mackinder climbed the mountain in 1899 and from a plane-table survey produced the first map of the glaciers (1900a, p. 564). In a fortnight of the rainy season in 1934, Troll and Wien (1949, p. 258) surveyed the Lewis Glacier by terrestrial photogrammetry and later produced a map contoured at 10-m intervals. As part of the program for the British National Committee for the International Geophysical Year, the Mt. Kenya Expedition 1957-58 studied Lewis Glacier.

The terminal area of Lewis Glacier is steep and moderately crevassed, and the firn area is smooth and rolling (Charnley, 1959, Figs. 6 and 10; Dutton, 1930, Fig. 32). The terminus is now an ice cliff behind a tarn at 4575 m, but in 1934 the tarn did not exist and the terminus was at 4475 m (Troll and Wien, 1949, Fig. 1).

Well-marked layering of the firn was found in pits and in a 20-m crevasse section. Two accumulation seasons were indicated, from March to May and from November to December, but the extreme variability of the seasonal accumulation was clearly shown (Charnley, 1959, p. 488). Stakes set out across the glacier about halfway down were resurveyed after five months: the maximum movement was at the rate of 4.6 m per year (Charnley, 1959, p. 487). A tachymetric survey of the glacier was carried out and plotted on a scale of 1:2500 with 10-m contour intervals. The results were compared with Troll's and Wien's 1934 survey and showed that the area had decreased from 0.46 sq. km to 0.36 sq. km. The ablation area had

thinned 10 m on average, and the accumulation area 0 m to 4 m. The total loss was estimated at 1,800,000 cubic meters (Charnley, 1959, p. 486).

Information about the other glaciers comes largely from a study of photographs, many of them taken by climbers. They will be described moving clockwise round the mountain from Lewis Glacier.

Melhuish Glacier is vestigial and occupies a niche on the mountain-side (Charnley, 1959, p. 484, Fig. 9).

Darwin Glacier is a short glacier formed mainly by avalanching from above. Two large avalanche cones lie at the foot of gullies (Firmin, 1946, photo p. 404; Howard, 1955, photo p. 274). It receded 60 m in the 20 years before 1945 (Spink, 1945, p. 216).

Diamond Glacier is steep and ends in an ice cliff from which avalanches fall to Darwin Glacier below (Dutton, 1930, Pl. 37; Howard, 1955, photo p. 274). It has changed little since 1934 (Charnley, 1959, p. 486). Mackinder (1900a, pp. 473 and 483) found the ice intensely hard, and named the glacier for that reason: three hours were needed for step-cutting instead of the expected 20 minutes.

Tyndall Glacier is moderately steep and crevassed. Recent moraines show that in the past it had a common terminus with Darwin Glacier (Firmin, 1946, photo p. 404). It is partly fed by avalanches from Forel and Heim glaciers above. In the late 1920's it was calving into Tyndall Tarn (Dutton, 1930, Pls. 33 and 48), but has now withdrawn about 100 m from the lake (Charnley, 1959, Fig. 1).

Forel and Heim glaciers cling to the steep slopes above Tyndall Glacier and end in vertical ice cliffs (Firmin, 1946, photo p. 404; Howard, 1955, photo p. 274). They have changed little since 1934 (Charnley, 1959, p. 487).

Joseph Glacier is steep and its feather-edge terminus appeared to be shrinking rapidly in 1930 (Tilman, 1938, photo p. 64).

Northey Glacier is steep and narrow and occupies a cleft (Tilman, 1938, photo p. 66; Spink, 1949, photo p. 281).

Krapf Glacier is narrow and ends above a precipice (Spink, 1949, photo p. 281).

Gregory Glacier was described by Mackinder (1900a, p. 483) as having many crevasses and well-developed seracs; it is steep and has shrunk greatly from a recent massive end moraine (Spink, 1949, photo p. 281) that is ice-cored in places (Charnley, 1959, p. 484).

As to snow and ice conditions in general, Gregory (1894a, p. 102) reported that snow conditions on the mountain were treacherous, very different to those in the Alps, with hard ice layers alternating with soft, spongy snow. Mackinder (1900a, p. 473) found the bare ice on all the glaciers and especially on Diamond Glacier to be exceptionally hard. Spink (1945, p. 215) has pointed out that the absence of snowdrifts probably shows that blizzards are rare. Arthur (1921, p. 18) noted that in the southern summer, south-facing glaciers had pinnacles 30 m to 45 m high while the north-facing glaciers had none: in the northern summer, the position was reversed (see Dutton, 1930, Pls. 44 and 45). Spink (1949, p. 278) has ascribed the poorer development of pinnacles compared to Kilimanjaro to the great steepness of the glaciers, which thus receive less insolation.

Kilimanjaro
(5895 m; 3°05'S, 37°21'E)

Kilimanjaro is a volcano but activity is at present confined to fumaroles. At the 1500-m level from which the mountain rises above the East African plateau, it is about 65 km wide from east to west (Busk, 1955a, p. 96). There are two main summits: highly dissected Mawenzi (5150 m) and little dissected Kibo (5895 m). In 1889 Mawenzi was bare during the dry season according to Meyer (1891, p. 322). A map by Klute (1920) from a 1912 survey marks the "Purtscheller-Firn" on the southwest side, and on the same side Gillman (1923, p. 5) noted a small, probably permanent snowbed. In the early 1930's Geilinger (1936, p. 7) reported a small glacier. An aerial photograph taken in 1928 by Mittelholzer (1930, Pl. 110) shows a large snowbed with a protalus rampart. Recently Humphries (1959, p. 475) has described the snowbeds as semipermanent.

The summit of Kibo consists of an outer crater about 3 km across with a fairly level floor on which glacier remnants lie, and an inner multiple crater containing the recent vent. On the outer slopes of the mountain, glaciers are best developed on the south and west sides because of greater precipitation and cloudiness. Climatic conditions appear to be complicated. Up to about 4000 m southeast trade winds blow from March to September, bringing the main rains between March and May or June. A secondary rainy season is in November and December, and the driest months are August to October. Above 4000 m the mountain penetrates into the northeast antitrades, which affect the north and east sides of the mountain, but set up a large eddy current that brings up moist air from below on the southwestern side (Geilinger, 1936, p. 8; Spink, 1945, photo p. 210). The average precipitation on the mountain in the five years 1945-49 decreased from a maximum of about 180 cm at 2850 m to about 18 cm at 4300 m and 0.7 cm at 5800 m (Salt, 1951, p. 161). According to Wyss-Dunant (1937, p. 223), the best weather is during December and January; in mid-January, however, he encountered waist-deep powder snow near the

summit (Wyss-Dunant, 1937, p. 229). Snowfall varies greatly from year to year; in 1961-62, for example, it was six times greater than the average for the previous four years (Segal, 1965, p. 126).

Meyer (1891, p. 318) noted the absence of surface moraine, and also (Meyer, 1891, p. 146) the scarcity of snow in the dry month of October: "What from beneath appeared to be snow of the most dazzling whiteness was in reality the weathered surface of the mantle of ice." Much of the higher parts of the glaciers were "covered with granular morsels, half-way between ice and snow, the surface of which was slushy during the day and afforded excellent footing" (Meyer, 1891, p. 316). When step-cutting, Meyer was impressed by the hardness of the ice; it was ". . . as hard as glass, and when broken, proved to be as clear . . . each step cost some twenty strokes of the axe" (Meyer, 1891, p. 145).

The glaciers of Kibo have been described as the ragged fringe of an ice cap whose central part has largely disintegrated (Humphries, 1959, p. 476). When the crater was first reached in 1889, no ice-free route existed over the crater rim (Meyer, 1891, p. 153) but by 1912 three ice-free notches had been uncovered on the southeast side (Klute, 1920, map). Today there may be more for Ratzel Glacier appears to be disintegrating (Downie, 1964, Pl. 2; compare with Meyer, 1891, p. 141). Geilinger (1936, p. 10) believed that disintegration began about 1933 when deeply etched patches appeared on the formerly smooth firn surface. In 1889, however, Meyer (1891, p. 147) had crossed the upper Ratzel Glacier and noted that the surface was "honeycombed in many places to a depth of over six feet [2 m] and weathered into countless grooves and ruts and pointed spikes. . . ." By 1945 most of the glacier surface was affected (Spink, 1945, p. 213, photo p. 212).

On the south side of Kibo, Rebmann, Decker, Kersten, and Heim glaciers fall steeply from a common accumulation area whose upper margin is a vertical wall of ice up to 12 m high that is receding down the mountainside away from the crater rim (Humphries, 1959, p. 477). The glaciers formerly avalanched over a precipice and formed a continuous regenerated glacier below, terminating behind a massive end moraine (Meyer, 1900, photo p. 222; Jaeger, 1909, Pls. 17 and 35; Klute, 1920 Pl. 1 and map). In a recent map (Reid, 1959) Rebmann and Decker glaciers are shown no longer extending below the precipice.

Northwest of Heim Glacier is the Great West Breach, where the crater rim is absent and the crater floor is terminated by precipices. In 1889 Meyer (1890, Pl. 2; 1891, p. 155) believed that the ice flowed from the crater floor through the notch and down the mountainside in a continuous stream. After a visit in 1898, however, he realized that the crater ice was separate from the glacier below (Meyer, 1900, photo p. 200 and map). The crater ice has shrunk greatly since Meyer's visits; the remnant near the Great West Breach is Furtwangler Glacier. Below the breach is Great

Baranco Glacier, which was only 10 m to 15 m from its innermost end moraine in 1912 (Klute, 1920, p. 119, Fig. 6). The clean surface makes it unlikely that the glacier has been fed by ice avalanching from Furtwangler Glacier in the recent past (Mittelholzer, 1930, Pl. 112).

Northwest of the Great West Breach, Great Penck, Little Penck, Drygalski, and Credner glaciers descend from an ice dome that smothers the crater rim and ends in a vertical cliff 30 m to 45 m high facing the center of the crater (Humphries, 1959, p. 477). Great Penck Glacier is the longest, extending 2.4 km from the rim at 5800 m to about 4580 m. It does not occupy a valley but flows down the mountainside "like a ribbon of toothpaste" (Humphries, 1959, p. 476). From the evidence of a one-meter-high end moraine, Klute (1920, p. 118) believed that the glacier had been stationary or advancing slightly between 1901 and 1906. Between 1906 and 1912 it receded 9.5 m, and at the latter date was 200 m from large, ice-cored end moraines. Since 1912 it has receded 300 m (Humphries, 1959, p. 476). Accumulation appears to be greatest between 4500 m and 5000 m, decreasing at higher levels (Humphries, 1959, p. 475).

The continuous ice cover along the northern rim of the crater, from the upper Penck glaciers to Hans Meyer Notch, is known as Northern Glacier. It extends only a short distance down the slope and ends in an ice cliff that was an impassable barrier 30 m to 35 m high in 1889 (Meyer, 1891, p. 179). The upper margin of the glacier is also a vertical wall 30 m to 45 m high on the crater floor. Disintegration of the surface of the eastern part of Northern Glacier was well under way in 1928 (see Mittelholzer, 1930, Pl. 116) and was further advanced in 1945 (Spink, 1945, p. 212).

The ice formations in the crater are believed to be the remnants of a formerly continuous cover (Humphries, 1959, p. 476). Observers are struck by their unusual appearance. Hall (1936, p. 456) described them as unlike anything he had ever seen before: "Ice-block glaciers from 100 to 200 ft. [30 m to 60 m] thick with vertical sides stood around in a detached array. . . ." The vertical faces of the ice bodies are fluted, and ice pinnacles on the surface are oriented in an east-west direction (Humphries, 1959, p. 477). Illustrations show that the disintegration was already far advanced in 1889 when the crater was first reached (Meyer, 1890, Pl. 2; 1900, p. 144). At that time the crater contained several large ice bodies. Shrinkage has apparently been uninterrupted since Meyer's time. Photographs from the same point by Uhlig in 1904 (Jaeger, 1909, Fig. 21, lower photo) and Gillman in 1921 show the "almost entire disappearance of the last connected ice patches on the central cone" (Gillman, 1923, pp. 12 and 19). Photographs of 1904 (Jaeger, 1909, Fig. 21, upper photo) and 1943 (Spink, 1945, p. 215) show great shrinkage, and in the next two years Spink found the recession "startling." Between 1953 and 1957 several small ice bodies disappeared (Humphries, 1959, p. 477).

Studies of the glaciers were begun in 1953 by Sheffield University and were continued in 1957 as part of the International Geophysical Year program. A photogrammetric survey was made of the southwest flank of Kibo (Humphries, 1959, p. 476). If the glaciers have been receding at a constant rate from the youngest end moraines, Downie (1964, p. 14) calculated that recession began about 200 years ago.

The Ruwenzori

The Ruwenzori is a mountain range extending about 120 km from the equator in a north-northeast direction. It rises abruptly from the equatorial forest of the Congo on the west and the savannah of Uganda on the east. Unlike the other high mountains of Central Africa, it is of non-volcanic origin, being composed of Precambrian gneisses and other metamorphic rocks (Bergstrom 1955, p. 469). Glaciers are confined to a group of six mountains in an area 12 km long by 5 km wide, lying just north of the equator between 0°20'N and 0°26'N; from north to south these are Mts. Emin, 4798 m; Gessi, 4715 m; Speke, 4890 m; Stanley, 5110 m; Baker, 4843 m; and Luigi di Savoia, 4626 m.

For much of the time the mountains are cloud-covered and during the drier, less cloudy seasons they are barely visible from the lowlands because of smoke haze (Osmaston, 1961, p. 103). Two periods of comparatively low precipitation occur in January-February and June-August: because of reduced snowfall and increased radiation the glaciers have negative regimes at these times. Dust from the deserts and ash from the grassland fires accumulate on the firn fields and because fires are more extensive in January and February, the stratification of the firn shows alternating thick and thin dirt bands. Five air masses, some dry and others moist, are believed to affect the area, and to affect different altitudes at different times (Whittow, 1960, p. 769). Precipitation is believed to reach a maximum of about 230 cm at 3300 m, falling to 115 cm near the summits at 5000 m, many times the amount on Kilimanjaro at the same height (Whittow and Shepherd, 1959, pp. 156-157). Many visitors have remarked on the prevailing lightness of the winds, but at the highest elevations strong winds are sometimes encountered: Shipton (1932, p. 92) spent four days in January on the Stanley Plateau, Mt. Stanley, and experienced high winds most of the time accompanied by continuous snow. Humphreys (1933, p. 492) had strong winds near the summit of Mt. Luigi di Savoia, and Filippi (1908, p. 277) mentioned violent weather with winds and lightning, and noted many fulgurites on the peaks.

The first information of glaciological value came from Stuhlmann, who approached the mountains from the west in 1891 but did not reach them. He was uncertain whether he saw glaciers or just heavy snow cover (Stuhlmann, 1894, p. 293); this is surprising for his excellent photograph of Mt. Stanley (Stuhlmann, 1894, Pl. 10; Filippi, 1908, p. 206) shows the glaciers clearly.

In 1900 the glaciers were reached for the first time by Moore (1901, pp. 301-303), who approached Mt. Baker from the south and saw "three superbly green glaciers" [West Baker, East Baker, and Moore]. He ascended East Baker Glacier. Later in the same year Johnston (1902, p. 180) reached Moore Glacier.

In 1906 an Italian expedition under the Duke of the Abruzzi explored the entire group of ice-covered mountains. Many glaciers were described and named, photographs were taken, and maps made (Filippi, 1908).

Humphreys (1927a, 1927b, and 1933) visited the mountains on foot twice in 1926 and five times in 1932. In 1931 he flew over and around the range, establishing that there were no more ice-covered peaks than those already known. He obtained many aerial photographs from heights near the tops of the mountains.

In 1932 a Belgian natural history expedition reached the Congo side of the range. Observations on the snowline and general descriptions of the glaciers were made and many photographs taken (Grunne and others, 1937).

In 1937-38 a group of German climbers made the first contour map of the central part of the range (Stumpp, 1952).

Since the end of the Second World War a considerable amount of glaciological work has been carried out. In 1949 the first detailed survey of a Ruwenzori glacier was made (Menzies, 1951) and in 1950 de Heinzelin (1952 and 1953) studied glacier recession on the west side of Mt. Stanley. In 1952 a glaciologist with the British Ruwenzori Expedition studied evidence for glacier variations, mapped Elena Glacier on Mt. Stanley with contours of 50 m, and made some meteorological studies (Bergstrom, 1955).

Osmaston (1961) visited the glaciers several times in the 1950's and made observations of variations and accumulation. In 1957 Makerere College [Uganda] sent an expedition to the glaciers in connection with the International Geophysical Year, and from 1957 to 1961 five more expeditions were sent. Glacier surveys were made and pits dug in the accumulation areas (Whittow and others, 1963).

Mount Emin

According to Whittow and others (1963, p. 591) the extent of the ice on Mt. Emin is not exactly known, but probably does not exceed 10 hectares. Small glaciers that lay on the eastern side of the mountain in 1906 (Filippi, 1908, photo p. 268) still existed in 1931 (Humphreys, 1933, photo p. 491) but had disappeared by 1959 (Whittow and others, 1963, Fig. 4). On other faces of the mountain, however, vestigial glaciers existed in 1955 (Osmaston, 1961, p. 102) and remnants of three glaciers--

Kraepelin, North Kraepelin, and Emin--probably remain today (Whittow and others, 1963, pp. 591-592).

Mount Gessi

Whittow and others (1963, p. 590) have estimated the area of ice on Mt. Gessi at about 25 hectares. A photograph taken in 1906 (Filippi, 1908, p. 270) shows the ice cover to be heaviest on Iolanda at the southern end where short, steep glaciers with common firn fields descended the southern and western faces. Iolanda I Glacier was described as ending in "broken sèracs on the brow of a cliff" (Filippi, 1908, p. 268). Only slight shrinkage was evident by 1931 (Humphreys, 1933, photo p. 491), but in 1959 the glaciers were dwindling fast (Whittow and others, 1963, p. 590). The number of glaciers has increased because of splitting. Gessi II Glacier, one of four on the west side of Gessi, was surveyed in 1963: all four were described as "shrinking pockets of ice" (Pasteur, 1964, p. 194).

Mount Speke

The ice-covered area on Mt. Speke is about 2500 m from north to south and 1200 m from east to west and consists of five glaciers: Grant, Vittorio Emanuele, East Johnston, Johnston, and Speke. The first two are joined by the ice cover continuing over the summit ridge. Vittorio Emanuele Glacier, largest in the Ruwenzori, is not a valley glacier but is broader than it is long, and has three short tongues terminating at a fairly uniform height on the mountainside. Like all the glaciers on Mt. Speke it has receded greatly since 1906 (Filippi, 1908, photo pp. 268-269; Whittow and others, 1963, Fig. 2).

The front part of an avalanche cone or small regenerated glacier with signs of considerable recent shrinkage situated below Speke Glacier can be seen in a 1906 photograph: the glacier above is not visible (Filippi, 1908, photo pp. 142-143). A 1926 photograph shows Speke Glacier ending in ice cliffs with an avalanche cone far below (Humphreys, 1927a, p. 521). This cone had disappeared by 1949, for Menzies (1951, p. 511) mentions only that no vegetation grew for 300 m below the terminus. He surveyed the tongue and made a map on a scale of 1:12,000, contoured at 25-foot intervals. He noted that the stream from the glacier carried no rock flour. The Makerere College IGY Ruwenzori team visited the glacier six times between January 1958 and July 1961 (Whittow and others, 1963, p. 595). The area of the glacier was found to be about 37.5 hectares, and the accumulation area from the ridge at 4814 m to the firn limit near 4570 m was about twice the ablation area. Crevassed areas lay near the snout and near the firn limit. The terminal area was mapped with 50-foot contours; part of the terminus had receded 64 m between 1950 and 1958. The greatest forward movement in a line of stones across the glacier was less than 1 m in 18 months (Whittow and Shepherd, 1959, pp. 156-157).

Mount Stanley

Mt. Stanley carries the most ice in the Ruwenzori. The highest peaks rise above the Stanley Plateau, a flat-lying snowfield that feeds seven glaciers: Margherita, East Stanley, Elena, West Elena, Moebius, West Stanley, and Alexandra. Four separate glaciers are at the southern end: Savoia, Coronation, Elizabeth, and Philip, and at the northern end is a cirque glacier, Northeast Margherita (Whittow and others, 1963, pp. 585-587).

Margherita Glacier is very steep, with many crevasses and seracs. In 1960 the terminal area was about to separate from the rest of the glacier (Whittow and others, 1963, p. 587).

The Italian Expedition used Elena Glacier as a route to the Stanley Plateau in 1906, but they did not visit the terminal area. The glacier was again visited by Humphreys in 1926 and 1927 and during a brief visit in 1949 Menzies (1951, p. 512) set up markers near the terminus for future measurement. In 1952 the British Ruwenzori Expedition surveyed Elena Glacier and investigated the economy. Four pits dug at different levels up to 4750 m revealed the alternating thick and thin dirt bands that were thought to have formed from June to July and from January to February, respectively. The firn limit was at about 4560 m. Above 4650 m ablation tended to increase and accumulation to decrease probably because of increasing radiation (Bergström, 1955, p. 474). During the several Makerere College expeditions of 1957-59 pits were dug higher up at about 4635 m, 4850 m, and 4920 m, the last being just below the highest peak, Margherita, 5110 m. The net accumulation for the year 1958 decreased from about 122 cm at the lowest pit to 86 cm at the upper pit (Whittow, 1960, p. 767). The thicker dirt bands were believed to be formed in January-February, in contrast to Bergström's conclusion (Whittow, 1960, p. 769). Osmaston (1961, p. 104) has concluded that the gross accumulation may total about 200 cm to 250 cm water equivalent with little decrease with altitude.

Moebius Glacier is narrow, steep, and heavily crevassed (Whittow and others, 1963, p. 587).

De Grunne (1937, p. 222) in 1932 and de Heinzelin (1955, quoted by Whittow and others, 1963, p. 585) in 1950 visited the glaciers on the western side of Mt. Stanley and found evidence for retreat. West Stanley Glacier is steep and has shrunk greatly since 1932 (cf Grunne and others, 1937, Pl. 77, and Bergström, 1955, Fig. 6). It shrank 245 m between 1940 and 1950 (Heinzelin, 1953, quoted by Whittow, 1959, p. 375).

Alexandra Glacier descends steeply in a series of steps.

Savoia Glacier, almost parallel-sided, measures about 600 m by 150 m and extends from 4880 m to 4550 m with a fairly low gradient. In August 1953 the snowline was at about 4675 m and in February 1954 at about 4750 m. A band of large crevasses extends across the glacier at about 4700 m. The positions of boulders on the surface have been surveyed: over a six-month period, a boulder near the center moved at the rate of 21 m a year, suggesting a complete turnover of the glacier in about a century. The glacier should therefore be very sensitive to changes in its economy and has been mentioned as suitable for glaciological study. Grey and turbid water issues from beneath the glacier, in contrast to the clear water reported from other glaciers in the Ruwenzori (Osmaston, 1961, p. 100).

Coronation Glacier is steep and heavily crevassed. In 1906 it was joined to Elena Glacier (Filippi, 1908, photo p. 200; Roccati, 1909, Pls. 16 and 28) and in 1938 it was still joined (Light, 1941, Pl. 198). In 1960 the two glaciers were separated by about 80 m (Whittow and others, 1963, p. 587).

Northeast Margherita Glacier was a single ice body in 1938 (Busk, 1954b, Pl. 1) but had split in two by the 1950's (Busk, 1955b, photo p. 106).

Snow conditions are variable on the Stanley Plateau. Garner (1952, p. 271) reported sinking to his knees after the sun had been out awhile, but early next morning the surface was firm. Many climbers have remarked on the peculiar snow and ice formations on the ridges and peaks above the Stanley Plateau. Filippi (1908, p. 225) mentioned the huge cornices, which were quite unlike anything in the Alps; masses of icicles supported them and no sign of any recent collapse was seen. Hodgkin (1942, p. 316) referred to the "curious snow canopies of Margherita," that resembled "a fungoid growth of wedding cake."

According to Heinzelin (1952, p. 138) the ice cover on the highest peaks has shrunk only slightly since the 1890's. However, comparison of photographs in 1891 (Stuhlmann, 1894, p. 288) and 1931 (Humphreys, 1933, p. 483) or 1950 (Busk, 1954a, p. 272) shows considerable shrinkage, particularly near the summit of Elena.

Mount Baker

Unlike Mt. Stanley and Mt. Speke, Mt. Baker has no large glacier on the summit, which is a narrow ridge with almost vertical cliffs on the north and west. Most of the ice is on the south and east sides (Whittow and others, 1963, p. 589). The Mt. Baker glaciers were the first in the Ruwenzori to be reached; Moore (1901, p. 303) ascended East Baker Glacier in 1900 and Johnston (1902, p. 152) reached Moore Glacier later the same year. In 1905 Freshfield (1906) reached Moore Glacier and photographed

it, and next year the Italian expedition, which climbed the mountain, painted some rocks at the terminus (Filippi, 1908, p. 259). Earlier the same year a British Museum party (Wollaston, 1908) had visited the mountain. About 1924 Thomas (1925) reached and photographed Moore Glacier.

Two short expeditions from Makerere College went to Mt. Baker in 1957 and 1958. Moore Glacier was selected for detailed study, and rocks near the terminus were marked for reference. Considerable shrinkage of the glacier since 1906 was noted, and the middle part had halved in width. The upper basin was thought to lie entirely below the firn limit, so that if conditions remained the same the glacier might disappear in 20 or 30 years (Whittow and others, 1963, p. 610). Moore and Baker glaciers, which had a common névé in 1906, had since separated, and Semper Glacier on the northwest side of the mountain had disappeared.

Mount Luigi di Savoia

In 1891 Mt. Luigi di Savoia was photographed from the west by Stuhlmann (1894, Pl. 11) and in 1906 from Mt. Baker by the Italian expedition (Filippi, 1908, pp. 246-247). A thin glacier then covered the flat summit of Weismann, and Stairs Glacier, a small ice mass with a very limited névé, lay between the Stairs and Stella.

In 1932 Humphreys approached the mountain from the east. Five small glaciers were at the head of the Kurugata valley, all showing signs of recent and rapid recession. None of the small glaciers still existing were fed by snowfields; they appeared to be fast disappearing, and he estimated that the mountain might be ice-free in a few years (Humphreys, 1933, pp. 490-493). Stairs Glacier had disappeared by 1931 (Humphreys, 1933, photo p. 490).

In 1934 or 1935, a British Museum party climbed Weismann, and photographs show that the summit glacier of Weismann still existed (Synge, 1938, Pls. 28 and 35). On the south side a glacier was visited and photographed; recent recession was evident and the glacier was broader than long (Synge, 1938, p. 47). In contrast to Humphreys' observation, the glacier was snow-covered almost to its terminus (Synge, 1938, Pls. 32 and 39).

In 1960 a party from Makerere College ascended Weismann; bad visibility prevented an accurate survey but they estimated the extent of the ice at no more than 4 hectares. Thomson Glacier extended eastward from the summit glacier. The condition of the glacier seen by Synge was not reported (Whittow and others, 1963, p. 592).

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Mount Kenya

Mackinder (1900b) [Less good reproductions are in Mackinder, 1900a, pp. 465 and 467.]

P. 102.	SW side, 1899.
P. 109.	Tyndall Glacier, 1899.

Arthur (1921) [Photographs taken in 1920?]

P. 17.	Tyndall Glacier.
P. 20.	Lewis and Darwin glaciers.

Dutton (1930) [Photographs probably taken in 1926.]

Pls. 19, 20, 22, 31, 34, 38, 40, and 42.	Lewis Glacier.
Pls. 33 and 48.	Tyndall Glacier.
Pls. 37.	Diamond Glacier.
Pls. 44 and 45.	Ice Pinnacles.

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Pls. 86-91.	Aerial views, 1928.

Tilman (1938) [Photographs taken in 1930.]

P. 64.	Joseph Glacier.
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Light (1941) [Photographs taken in 1938.]
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Douglas-Hamilton (1942)

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Hodgkin (1942)

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Spink (1945)

Facing p. 217.	Gregory and Lewis glaciers, 1945.

Firmin (1946)

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Spink (1949)
P. 281. — Lewis, Gregory, and Northey glaciers, aerial views, 1945.

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Figs. 3-6. — Lewis Glacier, 1934.

Howard (1955)
Pp. 272-274. — Gregory, Krapf, Northey, Lewis, Melhuish [?], Diamond, Forel, Heim, Darwin, and Tyndall glaciers [dates uncertain].

Charnley (1959)
Fig. 6. — Lewis Glacier, aerial view, 1957.
Fig. 9. — Diamond, Melhuish, and Lewis glaciers.
Figs. 10 and 11. — Upper Lewis Glacier, 1958.

Cliff (1964)
Photo 71. — Krapf and Northey glaciers.
Photo 76. — Krapf Glacier.

Nicol (1964)
Fig. 25. — Glaciers on N side.

Schneider (1964)
Pl. 5. — Lewis Glacier, 1963 [color].

Kilimanjaro

Meyer (1890)
Pl. 2. — Ice in Kibo crater [sketch].

_______ (1891)
P. 141. — Kibo, SE side.
P. 183. — Kibo, E side.

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About 20 photographs and some sketches of glaciers on Kibo, 1898.

Jaeger (1909)
Sixteen photographs of glaciers on Kibo, 1907.

Klute (1920)
Pl. 1. — Kibo, S side.
Pl. 6, Fig. 19. — Penck Glacier.
Pl. 8, Fig. 27. — Penck Glacier.
Pl. 8, Fig. 28. — Kibo crater, W side.

Gillman (1923)	
P. 4.	Kibo, SE side.
P. 12.	Ice on crater rim.
P. 13.	Ratzel Glacier.
Mittelholzer (1930)	
Pls. 107 and 111-115.	Glaciers on flanks of Kibo, aerial views, 1928.
Pls. 116-119.	Kibo crater, aerial views, 1928.
Geilinger (1936)	
Fig. 1.	Kibo, S side.
Figs. 2 and 4-10.	Ice in Kibo crater.
Fig. 3.	Kibo, W side.
Hall (1936)	
P. 457.	Kibo, E side, and ice in crater.
Wyss-Dunant (1937)	
Figs. 309-311.	Ice in Kibo crater, 1936.
Tilman (1938)	
Pp. 42, 48, and 52.	Ice in Kibo crater, 1930.
Light (1941)	
Pl. 170.	Kibo, E side, 1938.
Pl. 171.	Kibo, N side.
Pls. 172-173.	Kibo crater.
Spink (1945)	
Pp. 210 and 212-213.	Kibo, aerial views.
Pp. 214 and 215.	Ice in crater.
Berge der Welt (1948)	
Pl. 93.	Kibo, two aerial views of glaciers.
Pl. 94.	Kibo, crater and Northern Glacier.
Salt (1951)	
Fig. 4.	Credner, Drygalski, and Penck glaciers, 1948.
Figs. 5 and 6.	Drygalski Glacier, 1948.
Humphries (1959)	
Fig. 1.	Kibo, ice in crater, 1957.
Fig. 2.	Penck Glacier, 1957.
Downie (1964)	
Pl. 1.	Kibo, aerial view of NW side [undated].

Pl. 2.	Kibo, aerial view of SE side [undated].

Nicol (1964)

Fig. 27.	Kibo, S side.

The Ruwenzori

Filippi (1908)

Contains many photographs of all the ice-covered summits in 1906, taken on the Duke of the Abruzzi's expedition. Photographs from this expedition also appear in Abruzzi (1907), Roccati (1909), Dainelli (1933), and Berge der Welt (1948).

Humphreys (1927a)

Pp. 517, 521, and 524.	Mts. Baker, Stanley, Speke, and Emin, 1926.

______ (1927b)

Pp. 100-101.	Three panoramas, 1926.

______ (1933)

Pp. 482-490.	Several photographs, including aerial views of the mountains in 1931 and 1932.

Synge (1938)

Pl. 38.	Mts. Stanley, Speke, and Baker, 1934 or 1935.

Tilman (1938)

Pp. 102, 108, and 134.	Aerial photographs by Humphreys, 1931.

Light (1941)

Pls. 197-199.	Aerial views, 1938.

Mount Emin

Bere and Hicks (1946)

Pl. 7.	S side [1945?]

Whittow and others (1963)

Fig. 4.	E side, 1959.

Mount Gessi

Pasteur (1964)

Photo 49.	Mt. Gessi from Mt. Emin.

Mount Speke

Shipton (1932)
Pp. 88 and 94. Mts. Speke and Stanley, 1932.

Busk (1957)
Pl. 37. [Color photograph.]

Whittow and Shepherd (1959)
Fig. 1. Speke Glacier.

Osmaston (1961)
Fig. 1. 1926.
Fig. 2. 1951.
Figs. 3-5. Speke Glacier, vertical aerial views, 1952 and 1955.

Temple (1961)
Fig. 3. NE side, 1951.

Whittow and others (1963)
Figs. 8-11. Speke Glacier terminus, 1958 to 1961.

Pasteur (1964)
Photo 48. E side; Vittorio Emanuele Glacier.

Mount Stanley

Stuhlmann (1894)
Pl. 10. W side, 1891.

Barns (1922)
Pp. 127 and 134. W side, 1920.

Thomas (1925)
P. 105. Mt. Baker and Mt. Stanley [undated].

Wells (1930)
P. 119. Elena Glacier snout, 1928.

Grunne (1933)
Six photographs of Mt. Stanley from the W, 1932.

_______ and others (1937)
Twelve photographs of Mt. Stanley, 1932 [including the six in Grunne, 1933; one reproduced in Berge der Welt, 1948, Pl. 90].

Shipton (1932)
Pp. 88 and 94. Mts. Speke and Stanley, 1932.

Tilman (1938)	
P. 126.	Summit of Alexandra, 1930.
Bere (1946)	
P. 260.	E side, 1945.
______ and Hicks (1946)	
Pl. 3.	E side [1945?]
Garner (1952)	
P. 268.	1951.
Busk (1954a)	
P. 272.	W side, 1950
P. 274.	Elena and Coronation glaciers, 1953.
______ (1954b)	
Pp. 144-145.	Mt. Stanley, vertical aerial view of S part [1950?]; Mts. Stanley and Baker, oblique aerial view [1950?]; Mt. Stanley, oblique aerial view [1950?]; Mt. Stanley, W side, 1932; Elena and Coronation glaciers, 1953.
______ (1954c)	
Pl. 1.	N face of Margherita, 1938.
Bergström (1955)	
P. 469.	Several photographs of glaciers on Mt. Stanley, 1952.
Busk (1955b)	
P. 106.	Vertical aerial view of N part of Mt. Stanley [1950?].
______ (1957)	
Pl. 28.	Vertical aerial view of S part of Mt. Stanley [1950?].
Pls. 29 and 41.	Elena and Coronation glaciers.
Pls. 30, 31, and 38.	[P. 38 in color.]
Temple (1961)	
Fig. 1.	East Stanley and Margherita glaciers, 1958.
Fig. 20.	Coronation Glacier, 1959?
Figs. 21-22.	Savoia and Elena glaciers, 1958.

Zahl (1962)

P. 412.	E side.
P. 429.	Summit.
P. 430.	Elena Glacier, terminal cliff.
P. 431.	Coronation Glacier.
Pp. 432-433.	Summit [1958 or 1959, color].

Whittow and others (1963)

Figs. 14-17.	Elena Glacier terminus, 1959 to 1961.
Fig. 18.	Retreat stages of Savoia Glacier [sketch].

Mount Baker

Moore (1901)

P. 259.	East or West Baker Glacier, 1900.

Johnston (1902) [Photographs taken in 1900.]

Fig. 149.	Moore Glacier snout.
Figs. 150-152.	Moore Glacier margin.
Fig. 154.	Lower Moore Glacier.

Fisher (1905)

Pp. 174, 176, and 178.	Glaciers on SE side, 1903.

Freshfield (1906)

P. 193.	Moore Glacier snout, 1905.

Wollaston (1908)

P. 84.	1906.
P. 96.	Moore Glacier, 1906.

Thomas (1925)

P. 104.	Part of Moore Glacier [undated].
P. 105.	Mt. Baker and Mt. Stanley [undated].

Busk (1954b)

Pp. 144-145.	Mts. Stanley and Baker, oblique aerial view [1950?].

Whittow (1959)

P. 372.	Southern glaciers, 1957 or 1958.
P. 373.	Moore Glacier, 1957 or 1958.

_______ and others (1963)

Fig. 19.	Moore Glacier [same as Whittow, 1959, p. 373].

Map Sources

Mount Kenya

Mackinder (1900a) Facing p. 564.	Summit of Mt. Kenya [1:40,000].
Troll and Wien (1949) Fig. 1.	Die Gipfelregion des Mount Kenya mit dem Lewis-Gletscher, nach der photogrammetrischen Aufnahme vom Mai 1934, 1:13,333. [Contour interval 10 m.]
Charnley (1959) Fig. 2.	The Lewis Glacier: Outline Map of the Lewis Glacier in January 1958 [1:9,000; contour interval 100 m].

Directorate of Overseas Surveys, London. Mount Kenya, D.O.S. 302, 1:25,000, 2nd ed., 1964. [Shaded relief map with contours.]

Schneider (1964) Accompanying map.	Mount Kenya, 1:10,000. [From terrestrial photogrammetry; contour interval 20 m.]

Kilimanjaro

Meyer (1891) P. 122.	A Map of the Upper Kilimanjaro, 1:85,000.
________ (1900) Accompanying map.	Specialkarte des Kilimandjaro, 1:100,000. [Published by Dietrich Reimer, Berlin.]
Jaeger (1909) Accompanying map.	Kartenskizze des Westlichen Kibo, 1:40,000. [Shows Heim to Credner glaciers.]
Klute (1920) Accompanying map.	Karte der Hochregion des Kilimandscharo-Gebirges nach stereophotogrammetrischen Augnahmen flüchtigen Triangulationen u. Krokis aufgenommen

von Fritz Klute u. Eduard Oehler, 1:50,000. [Based on stereophotogrammetry of 1912.]

Reid (1959)
Accompanying map. — Kibo, 1:25,000. [Based on Klute, 1920, accompanying map, amended to 1953.]

Directorate of Overseas Surveys, London. East Africa (Tanganyika), D.O.S. 422, 1:50,000.
Sheet 56/2 — Kilimanjaro, 1964. [Contour map of Kibo and surrounding area, including Mawenzi.]

Downie (1964)
Pl. 3. — Moraines of Mount Kilimanjaro, Northeast Tanganyika, 1:100,000.

Directorate of Overseas Surveys, London. East Africa (Tanzania/Kenya), D.O.S. 522, 1:100,000.
Special Sheet — Kilimanjaro, 1965.

The Ruwenzori

Abruzzi (1907)
Accompanying map. — The Peaks, Passes & Glaciers of Ruwenzori, 1:50,000. [Published by the Royal Geographical Society, London.]

Freshfield (1907)
P. 392. — The Peaks, Passes & Glaciers of Ruwenzori, 1:50,000. [Reproduction of Abruzzi, 1907, p. 248.]

Filippi (1908)
Accompanying map. — The Peaks, Passes and Glaciers of Ruwenzori, a Sketch Map Based upon the Observations Taken by the Expedition of H.R.H. Prince Louis of Savoy, Duke of the Abruzzi, 1:40,000. [Compiled and drawn by the Hydrographical Institute of the Royal Italian Navy, Genoa, 1906.]

Grunne and others (1937)
Map 14. — Exploration Scientifique de Ruwenzori, 1932, 1:25,000. [Shows the glaciers of Mt. Stanley.]

Map 15. — Exploration Scientifique de Ruwenzori, 1932, 1:50,000. [Shows the glaciers of Mts. Emin, Gessi, Speke, Stanley, and Baker.]

Menzies (1951)
Fig. 2. — The Speke Icefall [1:12,000; contour interval 25 ft.].

Stumpp (1952)
Accompanying map. — Zentralgruppe des Ruwenzori-Gebirges, 1:25,000. [Surveyed in 1937-1938.]

Bergström (1955)
Fig. 8. — The Elena Glacier, Showing the Present Ice Margin and, to the Right, the Moraines [1:15,000; contour interval 500 ft.].

Directorate of Overseas Surveys, London. Uganda, D.O.S. 26, 1:50,000. Sheet 65/II Margherita, 1958. [Contour map.]

Whittow (1959)
Fig. 1. — The Glaciers of Mount Baker [1:66,000].

_______ and Shepherd (1959)
Fig. 2. — Snout of the Speke Glacier, Ruwenzori, Uganda: Recent Changes [1:2750; contour interval 50 ft.].

_______ and others (1963)
Fig. 1. — Central Ruwenzori: Approximate Ice Distribution in 1960, with the Routes Followed by the Makerere College Expeditions [1:90,000].

Fig. 5. — Snout of the Speke Glacier: Recent Changes [1:2200; contour interval 50 ft.; same as Whittow and Shepherd, 1959, Fig. 2].

Fig. 11. — The Elena Glacier: Recent Changes [1:9000; contour interval 100 ft.]

Directorate of Overseas Surveys, London. Central Ruwenzori D.O.S. 326, 1:25,000, 1962. [Shaded relief map with contours.]

GLACIERS OF NEW GUINEA

A mountain chain about 2500 km long extends through the equatorial island of New Guinea. Only the higher summits in the western part rise above the snowline, the main concentration of glaciers being in the massif extending northwest from Oost Carstensz Top (5010 m) and Ngga Poeloe (5030 m), the island's highest mountain. Outside this group, three widely separated mountains, Idenburg Top, Wilhelmina Top, and Juliana Top, carry small summit glaciers. [The glaciers are in territory now controlled by Indonesia. All the known investigations were made in the days of Dutch control, however, and to avoid confusion Dutch place names are used in this report.]

Carstensz Massif

The Carstensz massif was first penetrated in 1913 by Wollaston and Van de Water, who reached the hanging glaciers on the south side of Carstensz Pyramide. They estimated the snowline at 4320 m (Wollaston, 1914a, p. 257). In 1936 Colijn, Dozy, and Wissel ascended the glaciers and reached the summits of Ngga Poeloe and Oost Carstensz Top. The reports of this expedition still constitute the most extensive source of information about the glaciers of New Guinea. In 1961 Temple and others reached the Noord Wand, the precipitous north wall of the range (Temple, 1962), and in 1962 Harrer and Temple climbed Carstensz Pyramide and many other peaks (Temple, 1963a).

The glaciers of the Carstensz massif extend about 10 km in a northwesterly direction and the ice-covered area was estimated at 14.5 sq. km in 1936 (Dozy, 1939, p. 45). The general character of the glaciers may be judged from the aerial photographs taken at that time. In the northwest is the Noordwand-firn, a long, narrow icefield occupying a tilted platform above the 1200-m precipice of the Noord Wand. In 1936 a few short ice tongues extended down the precipice, but elsewhere on this side the glacier ended in convex ice cliffs. In places near the glacier margin were many broad and widely spaced crevasses, but the central part of the icefield was smooth and undulating and uncrevassed for its whole length. On the southwest side the icefield thinned out below the firn limit. Crevassing was moderate and the ice margin was irregular with no definite glacier tongues. In 1936 the Noordwand-firn was the continuous ice cover extending northwestward from Ngga Poeloe (Dozy, 1939, p. 47), but by 1962 the ice-free New Zealand Pass divided the glacier (Temple, 1963a, p. 83). The present Noordwand-firn is here considered to extend northwest of New Zealand Pass.

Southeast of New Zealand Pass are Meren and Carstensz glaciers, the only valley glaciers in New Guinea. In 1936 the tongue of Meren Glacier was much crevassed (Dozy, 1939, Pl. 14; Colijn, 1937a, p. 160; 1937b,

p. 184), but the crevasses decreased up-glacier and the Midden-firn, constituting the southern part of the accumulation area, was a smooth and unbroken firn field (Colijn, 1937a, pp. 164 and 165). A steep snow ramp led from the Midden-firn to the Carstensz-firn 100 m above (Dozy, 1939, Pl. 1; Colijn, 1937a, p. 165; 1937b, p. 185). Like Meren Glacier, the Carstensz was much crevassed in its lower parts; both glaciers, however, were ascended without great difficulty by the 1936 expedition. The iceshed bounding the Carstensz-firn extends along the ice-covered ridge connecting Carstensz Pyramide with Oost Carstensz Top; in 1936 on the south side of the iceshed lay the short, steep, and broken Wollaston and Van de Water glaciers (Dozy, 1939, Pl. 2; Colijn, 1937a, pp. 36, 181, and 188; Wollaston, 1914a, p. 257; 1914b, p. 304; Kasberg, 1956, Pl. 24). By 1962, Wollaston Glacier had disappeared (Temple, 1963a, p. 84).

In 1936 young moraines with little or no vegetation lay in front of the Meren and Carstensz glacier tongues. Rather older moraines with enclosed lagoons extended about 2 km beyond (Dozy, 1939, pp. 47 and 49, and Pl. 7; Colijn, 1937a, pp. 140, 149, and 157). Cairns were erected in that year at measured distances from the ice margins, and the 1962 expedition found that Meren Glacier had receded 800 m and Carstensz Glacier over 400 m during the 26-year interval (Temple, 1963a, p. 84).

In 1936 on the precipitous south side of Carstensz Pyramide and just below the summit ridge was a continuous long cliff glacier from which occasional avalanches fell (Dozy, 1939, p. 49, and Pl. 3; Colijn, 1937a, pp. 44 and 145). A 1962 photograph shows considerable reduction of this ice cover (Temple, 1963a, 3rd photo).

Idenburg Top

About 8 km west of the northwest end of the Noordwand-firn is the isolated summit glacier on Idenburg Top (ca. 4750 m). It appears in the distance in a 1936 photograph as a small dome-shaped summit glacier and in the expedition's map it is shown about 800 m long (Colijn, 1937a, p. 176; map in Colijn, 1937a and 1937b). The mountain was climbed in 1962 by Harrer and Temple (Temple, 1963a, p. 89).

Wilhelmina Top

In 1905, snow and ice were estimated to extend 350 m below the summit of Wilhelmina Top (4730 m) (Tijdschrift, 1908). When the mountain was climbed in 1913, the firn field was described as being long, and about 200 m wide, but probably very thin. It was considered to be a firn field only or possibly an embryonic glacier; terminal moraine development was very slight and lateral moraines were not found (Tijdschrift, 1913, p. 793; Pulle, 1914?, p. 169). This firn field can be seen in a photograph

(Lorentz, 1913, frontispiece). In other photographs (Pulle, 1914?, p. 170; Le Roux, 1935, p. 109; Archbold and others, 1942, Pls. 33-35) a small summit glacier can be seen as well as a long firn- or ice-filled valley. The mountain was climbed again in 1921 (Brongersma and Venema, 1963, p. 228) and when visited by a Dutch-American botanical expedition in 1938-39, the summit still supported a small area of permanent snow or ice (Brass, 1941, p. 277, and Pl. 1, Fig. 1). In 1963 or 1964 a Japanese-Indonesian party climbed the mountain, which they referred to as "Mount Sukarno" (Alpine Journal, 1964, p. 291).

Juliana Top

Juliana Top (4640 m) was observed from the distance in 1909 and sketches of the ice cover were made (Tijdschrift, 1910, p. 1008). The mountain was photographed from the air in 1945 when a small summit glacier ended in steep cliffs above precipices (Verstappen, 1952, p. 429). Comparison of the 1909 sketch and 1945 photograph is difficult.

In 1959 the mountain was climbed and in the 14 years since the aerial photographs had been taken, the ice had receded greatly (Verstappen, 1960, p. 311). In photographs taken at this time a roughly circular summit glacier rests on sloping ground, ending at a precipice on the southern side and on bare rock on the north. The surface steepens rapidly near the edge where a few radial crevasses can be seen (Brongersma and Venema, 1963, Pl. 43). The ice was estimated to be 100 m thick (Brongersma and Venema, 1963, p. 249) and the snowline was at 4580 m (Verstappen, 1960, p. 305).

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Photographic Sources

Much the most complete coverage of the glaciers of the Carstensz massif is given by Colijn (1937a) from the 1936 expedition. Smaller but more generally accessible selections are Colijn (1937b) and Dozy (1939). Apart from the published material, photographs were taken by the U. S. Army Air Force in 1945 (Verstappen, 1960, p. 306).

Carstensz Massif

Wollaston (1914a)	
P. 252.	Wollaston and Van de Water glaciers and hanging glaciers on Carstensz Pyramide.
P. 257.	Probably Wollaston Glacier.
_______ (1914b)	
P. 297.	Wollaston and Van de Water glaciers and hanging glaciers on Carstensz Pyramide [same as 1914a, p. 252].
P. 304.	Probably Wollaston Glacier.
Colijn (1937a)	
P. 36.	Carstensz Pyramide and Wollaston and Van de Water glaciers.
P. 37.	Upper Carstensz-firn.
P. 44.	Carstensz Pyramide with hanging glaciers [same as Dozy, 1939, Pl. 3].
P. 45.	Carstensz Pyramide, distant.
P. 141.	Meren Glacier [cf Colijn, 1937b, 5th photo].
P. 145.	Carstensz Pyramide, Carstensz and Meren glaciers, and Noordwand-firn.
P. 149.	Recent moraines, Meren valley.
P. 156.	Carstensz Glacier tongue.
P. 160.	Upper Meren Glacier.
Pp. 164 and 172.	Midden-firn.
P. 180.	Wollaston and Van de Water glaciers.
P. 181.	Carstensz and Wollaston glaciers.
P. 188.	Iceshed between Carstensz-firn and Wollaston Glacier.
P. 189.	Carstensz and Meren glaciers.
P. 192.	Glacier tongue.
P. 193.	Noordwand-firn, aerial view.
P. 197.	Carstensz Glacier margin.
P. 204.	Cairn near margin of Carstensz Glacier.

________ (1937b)	
Photo 5.	Meren Glacier.
Photo 6.	Meren and Carstensz glacier tongues [cf Dozy, 1939, Pl. 4].
Photo 8.	Midden-firn.
Photo 9.	Part of upper Carstensz Glacier.
________ (1937c)	
Pl. 9.	Upper Meren Glacier.
Pl. 10.	Midden-firn.
Pl. 11.	Meren Glacier.
Pl. 12.	Top of Ngga Poeloe.
Pl. 14.	Carstensz and Meren glaciers, tongues.
Pl. 15.	Upper Carstensz Glacier.
Dozy (1939)	
Pl. 1.	Noordwand-firn and Meren and Carstensz glaciers.
Pl. 2.	Wollaston and Van de Water glaciers and hanging glaciers on Carstensz Pyramide.
Pl. 3.	Carstensz Pyramide, hanging glacier on S side.
Pl. 4.	Carstensz and Meren glaciers.
Pls. 5 and 6.	Ponds on lower Meren Glacier.
Pl. 7.	Abandoned moraines in Meren valley.
Weber (1948)	
Facing p. 281, Pl. 34.	Carstensz Pyramide and Noordwand-firn, aerial view [same as Colijn, 1937a, p. 145].
Kasberg (1956)	
P. 59, Pl. 24.	Wollaston and Van de Water glaciers [undated].
Temple (1962)	
Pp. 99 and 114.	Noord Wand, small ice tongues at top of cliffs.
________ (1963a)	
Photo 2.	Carstensz Pyramide, from recently deglaciated New Zealand Pass.
Photo 3.	Carstensz Pyramide, S side.
Photo 4.	Meren Glacier tongue, 1962.
________ (1963b)	
P. 52.	Noord Wand.

Idenburg Top

Colijn (1937a) P. 176.	Idenburg Top, from Ngga Poeloe.
Le Roux (1948) Pls. 6 and 7.	Aerial views, Idenburg Top barely visible in the distance.

Wilhelmina Top

Lorentz (1913) Frontispiece.	Firn field near summit.
Pulle (1914?) P. 170, Pl. 27.	Summit glacier, 1913.
Le Roux (1935) P. 109, Pl. 22. P. 111, Pl. 28.	S. Side.
Brass (1941) Pl. 1, Fig. 1.	Aerial view.
Archbold and others (1942) Pls. 33-35.	Aerial views.

Juliana Top

Verstappen (1952) P. 429.	Summit glacier, 1945.
Brongersma and Venema (1963) P. 240. P. 289.	Two aerial photographs, color. Glacier on Juliana Top, from below.

Map Sources

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Colijn (1937a) Facing p. 286.	Schetskaart van het Nassau Gebergte (Carstensz Groep), 1:80,000. [Shows Carstensz massif and Idenburg Top.]
_______ (1937b) Accompanying map.	[Same as Colijn, 1937a, facing p. 286.]
Dozy (1938) P. 47.	Kartenskizze der Carstensz-Gruppe, 1:50,000. [Sketch map of Noordwand-firn and adjacent glaciers.]

GLACIERS OF NEW ZEALAND

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Except for those on Mt. Ruapehu in North Island, all the glaciers in New Zealand are in South Island. The first observations were made in 1862, and most of the investigations since then have been carried out on five easily accessible glaciers in the Mt. Cook area: Fox and Franz Josef on the west side, and Tasman, Hooker, and Mueller on the east side. In recent years the program of studies by the New Zealand Geological Survey has been stepped up and much more data should soon be available. Information about glaciers in other areas must be sought mainly in travelers' and climbers' accounts and from photography. In summer 1964-65 oblique aerial photographs were taken of 29 glaciers in the central part of the range (see Photographic Sources).

Because altitudes and contours on New Zealand maps are in feet, these units are used as well as the metric equivalent, where relevant.

Glaciers of North Island

Glaciers in North Island are confined to Mt. Ruapehu (2797 m, or 9175 ft.), the lowest reaching 2070 m (6800 ft.). Little is known about the past fluctuations of these small glaciers (Krenek, 1959), which must have been affected to some extent by the intermittent volcanic activity (see Odell, 1955, Fig. 1). Six glaciers are shown on a recent map (O'Shea, 1959, Fig. 1) but recent shrinkage has split Whakapapa Glacier in two (Heine, 1962, p. 175). In 1960-62 the mountain was below the firn limit and the glaciers had no accumulation areas (Heine, 1962, p. 178). In 1960 permanent photographic stations were set up and annual coverage of all the glaciers was planned, photography to take place in March or April (Heine, 1963, p. 261).

Glaciers of South Island

Glaciers lie along the main range of South Island between 42°45'S and 44°53'S with the main concentration and the largest glaciers in the Mt. Cook area near 43°35'S. Many of the glacier tongues, particularly on the eastern side of the range, are completely debris-covered.

The mountains have been considered in five divisions and the glaciers in each division grouped by catchment basin; where necessary the latter have been subdivided by tributary river. Thus a catchment may figure in two adjacent mountain divisions. The divisions are:

Arthur's Pass to Mount Cook National Park
Mount Cook and Westland National Parks
Mount Cook National Park to Haast Pass Road
Haast Pass Road to Fiordland National Park
Fiordland National Park

Arthur's Pass to Mount Cook National Park

(1) Waimakariri Catchment

The glaciers of the Waimakariri catchment are all cirque glaciers; little information is available about them apart from photographs. Crow Glacier ends at about 1370 m (4500 ft.) (Arthur's Pass, 1960, p. 69) and is steep, much crevassed, and carries little surface debris. Cahill Glacier is similar but Marmaduke Dixon Glacier is less steep.

(2) Hokitika Catchment

(a) Whitcombe River. Six glaciers with Whitcombe River drainage are named on maps. Wilkinson Glacier is virtually an icefall in its upper half and drops 1200 meters in a horizontal distance of 2000 meters; when seen in 1949 from just over 2 km away, it appeared to be advancing or about to advance. At the same time Sale Glacier had receded considerably since the 1860's (Gage, 1951a, p. 506).

(b) Hokitika River. Several small glaciers lie on the peaks between Hokitika Saddle and Mathias Pass.

(3) Rakaia Catchment

Glaciers lie round the headwaters of the Wilberforce, Mathias, Rakaia, and Cameron rivers. Those round the Wilberforce and Mathias are not known to have been studied.

(a) Rakaia River. The mountains at the head of the Rakaia River are heavily ice-covered and contain the northernmost glaciers of any size in the Southern Alps. The largest is Ramsay Glacier, about 8 km long. The complete debris cover of the lower part was said in 1910 to be thicker and to contain larger boulders than on any other New Zealand glacier (Speight and others, 1911, p. 330). Photographs show that part way up the glacier the slope is moderate and crevasses are few. In 1866 the Rakaia River flowed past its terminus (Haast, 1879, p. 206). By 1910 the terminus had receded about 200 meters and below the junction with Clarke Glacier the surface had lowered about 20 meters; higher up the ice surface was still level with the lateral moraine. By 1932 the terminus had receded a short distance only, and downwasting was still

confined to the lower half. By 1949 the terminus was about 500 meters from its 1866 position and the ice surface above Clarke Glacier had shrunk about 60 meters from the lateral moraine (Gage, 1951a, p. 506).

Lyell Glacier has a heavy debris cover in its lower part but in 1910 was fairly smooth and little crevassed higher up (Speight and others, 1911, p. 330). In 1866 it was within 800 meters of Ramsay Glacier. The terminus receded about 800 meters from 1865 to 1911, little from 1911 to 1933, and 1000 meters from 1933 to 1949 when a small proglacial lake had formed (Gage, 1951a, p. 504). A recent photograph shows the lake considerably larger than in 1949. The terminal positions of Ramsay and Lyell glaciers in 1866, 1910, 1933, and 1949 are shown on a diagram by Gage (1951a, p. 505).

Kark and Armoury are short, steep glaciers on Mt. Arrowsmith, a massif to the east of the main range.

(b) Cameron River. Cameron and Douglas glaciers lie on Mt. Arrowsmith. Cameron Glacier has two branches, the northern one being very crevassed and confined in a narrow, steep-sided valley; it tends to override the southern branch, which may be supplying little or no ice to the main trunk. The lower part of the glacier, the southern fringe of the trunk, and the icefall of the southern branch have a heavy debris cover, but elsewhere the surface is clean. Stranded moraines lie 90 m above the ice surface, and at the junction of the two branches the surface lowered 60 m between 1910 and 1951 while the terminal position changed little (Gage, 1951b, p. 138).

(4) Ashburton Catchment

In 1862 Ashburton Glacier was advancing and pushing a large moraine before it (Hochstetter, 1863, quoted by Kolb, 1958, p. 136). About 1910 it appeared to be readvancing onto the moraine after recent shrinkage (Speight and others, 1911, p. 326).

(5) Waitaha Catchment

Several small glaciers drain into the Waitaha River but are not known to have been studied.

(6) Wanganui Catchment

Thirteen glaciers with Wanganui drainage are named on maps. In 1934 Adams Glacier ended on Adams Flats at 850 m (2800 ft.) and the lowest 400 m was very steep (Pascoe, 1940, p. 417). Photographs show it and its tributary Beelzebub Glacier to be very crevassed and narrowly confined between steep walls. Between 1936 and 1959 the tongue receded a considerable distance up the gorge, and by 1965 an aerial photograph

shows that Adams and Beelzebub glaciers had separated; Beelzebub is now the main glacier and Adams Glacier ends a considerable distance above it.

(7) Poerua Catchment

Aerial photographs show that in 1965 South Poerua Glacier was reconstituted from a hanging glacier high up on Mt. Kensington. It has a heavy cover and has shrunk greatly from recent end moraines.

(8) Rangitata Catchment

Two glaciers with Lawrence River drainage and five with Havelock River drainage are named on maps but are not known to have been studied. Ten glaciers with Clyde River drainage are named.

(a) Clyde River. When Haast visited McCoy Glacier in 1866 it was entirely debris-covered, but smaller glaciers on either side were clean (Haast, 1879, p. 13).

Colin Campbell Glacier was also debris-covered and ended in an ice wall 40 meters high. The terminus apparently reached the outlet stream of Agnes Glacier, which ended 40 meters above (Haast, 1879, p. 14). A recent map shows a subsequent terminal recession of about a kilometer.

Frances Glacier ended at 1070 m (3500 ft.) in 1934 (Pascoe, 1940, p. 417).

(9) Whataroa Catchment

(a) Perth River. Ten glaciers with Perth River drainage are named on maps. The Garden of Eden, "a terraced ice plateau many miles long," has The Serpent, Abel, Cain, Eve, and Perth glaciers as outlets. The first four are very steep and are sources of avalanches. Perth Glacier is badly crevassed only between about 1800 m and 2000 m (6000 and 6500 ft.); in 1934 it was covered with debris for 700 meters back from the terminus at 1040 m (3400 ft.) (Pascoe, 1940, pp. 414 and 417).

Barlow Glacier is steep and narrow and in 1965 had shrunk greatly from recent end moraines.

(b) Whataroa River. Seven glaciers draining into the Whataroa River are named on maps, much the largest being Whymper Glacier, about 8 km long. Photographs show that this glacier is avalanche-fed; the trunk is fairly flat and completely debris-covered.

Gino Watkins Glacier is steep and in 1965 had shrunk greatly from recent end moraines.

Mount Cook and Westland National Parks

The Mount Cook National Park and the adjacent Westland National Park contain the highest mountains and the largest glaciers in New Zealand. Many of the glaciers are easily accessible and have attracted investigators from early times. The tongues of many glaciers, particularly on the eastern side, are completely debris-covered.

(10) Waitaki Catchment

(a) Godley River. Godley and Classen glaciers, 11 and 8 km long respectively, are the source of the Godley River. When discovered by Haast in 1862 they appeared to be advancing and were separated by "a few chains only" (Haast, 1879, p. 20). At the terminus of Classen Glacier, several older moraines were being buried by the moraine under formation (Haast, 1879, p. 21). Godley Glacier receded at least 1200 meters between 1862 and 1939 (Speight, 1939, p. 58), and recession was marked in the twenty years after 1933 (Hewitt and Davidson, 1954, p. 80). The 1965 aerial photographs show that both glaciers have receded about 2 km from their maximim extent and their debris-covered tongues end in proglacial lakes.

A few small glaciers lie on Mt. D'Archiac. Fitzgerald Glacier, which was reported only a few hundred yards from Godley Glacier in 1862 (Haast, 1879, p. 201), is now about 3 km away according to recent maps. (Another Fitzgerald Glacier is in the Karangarua catchment, Westland National Park.)

(b) Cass River. Small glaciers lie on the crest of the Liebig Range just outside the park boundaries. Huxley Glacier was described by Haast (1879, p. 26) as steep with an icefall just above the terminus.

(c) Murchison River. Murchison Glacier, about 12 km long, appeared to be advancing in 1862 (Haast, 1864, p. 93). Between 1891 and 1935 the western part of the front receded about 700 meters, mostly after 1914. In 1891 Brodrick made some very brief movement studies from fixed points across the glacier near midcourse and obtained a maximum reading of nearly 23 cm a day near the center of the glacier. Between 1914 and 1935 a prominent patch of surface moraine moved 2400 m down the glacier, or 26 cm per day (Rose, 1937, p. 454).

Onslow and Cascade glaciers joined the Murchison in 1891, but by 1935 Onslow was separated by 90 m, and Cascade ended above a 300-m precipice 800 m horizontally from the Murchison (Rose, 1937, pp. 454-455).

In 1935 Wheeler Glacier was connected to the Murchison by a moraine-covered tongue of ice "insignificant in size" (Rose, 1937, p. 457).

Baker and Dixon glaciers, tributaries of the Murchison, were expanding in 1890 (Harper, 1893, p. 41). By 1935 Baker Glacier had shrunk considerably but was still very active (Rose, 1937, p. 455). A more recent photograph shows it to be a reconstituted glacier (*The Canterbury Mountaineer*, 1952-53, photo p. 64).

In 1914 Harper Glacier joined and flowed alongside Murchison Glacier for about 400 m, but by 1935 it was very nearly or entirely separated (Rose, 1937, p. 457). The 1965 aerial photographs show Murchison Glacier to be completely debris-covered below its junction with Mannering Glacier, and a proglacial lake is beginning to form.

(d) Tasman River. Tasman Glacier is a dendritic valley glacier 28 km long, the longest in New Zealand. It heads as a transection glacier at Tasman Saddle, which it shares with the Murchison (Goldthwait and McKellar, 1962, p. 214). The 10 km of the glacier below the junction with Ball Glacier are almost entirely debris-covered, but for about 12 km above Ball Glacier the surface carries little debris, is of low gradient, and is easy to travel upon.

Tasman Glacier advanced 800 m between 1862 and 1869 (Haast, 1870, p. 434). In 1882 the terminus was probably advancing (Green, 1882, p. 7); from 1890 to 1906 it advanced 15 m to 45 m, and in 1939 it was slightly further forward than in 1890 (Speight, 1940, p. 137). The position has changed little since (Goldthwait and McKellar, 1962, p. 214) but the surface has lowered considerably. In 1882 the ice in places overtopped the lateral moraine by 6 m near Ball Hut (Green, 1883, p. 199), and in 1893 no shrinkage was evident. By 1939 the ice surface was 46 m below the moraine ridge (Speight, 1940, p. 136), and about 1960 was 60 m below both at Ball Hut and at Malte Brun Hut 9 km up the glacier, according to Goldthwait and McKellar (1962, p. 214). In 1962 Skinner (1964, p. 801) repeated Brodrick's 1890 to 1891 survey line across the glacier and concluded that the average lowering of the surface of the section near Ball Hut was about 90 m.

The only regimen study on a New Zealand glacier was carried out on Tasman Glacier from 1957 to 1960. Studies were limited to the left band of the Tasman ice, originating in névés to the east of Rudolph Glacier. The firn limit is at about 1800 m (6000 ft.) and the firn area covers about 23 sq. km. Above 2200 m (7200 ft.), where most of the snow accumulates, precipitation is about 700 cm (275 in.) per year. A strongly negative regimen was suggested for the years of study. A line of poles was set up across the glacier at 1590 m (5200 ft.), 2.5 km below the firn limit; the greatest velocity in winter was 51 cm per day, increasing 20 percent in summer (Goldthwait and McKellar, 1962).

Many of the western tributaries, such as Ball Glacier and the spectacular Hochstetter Glacier, are very steep. They may contribute more

ice to the terminus than does the firn field that was studied (Goldthwait and McKellar, 1962, p. 211).

(e) Hooker River. Both Hooker and Mueller glaciers are between 8 and 10 km long and each consists of a gently sloping trunk with heavy debris cover fed by very steep tributary glaciers. In 1862 Mueller Glacier reached Mt. Wakefield but had retreated 180 to 280 m by 1886, when its surface was 15 to 30 m below a fresh lateral moraine (Hutton, 1888, pp. 436-438). It may have readvanced between 1895 and 1906 (Speight, 1939, p. 59). The 1965 aerial photographs show that both glaciers have thinned considerably but receded little.

The glaciers on Mt. Sefton, some of which reach Mueller Glacier, are very steep icefalls.

(11) Waiho Catchment

(a) Callery River. Spencer Glacier, about 7 km long, is the largest glacier in the Callery drainage. Several very steep icefalls combine to form the trunk, which carries much surface moraine and is "difficult and laborious" to travel on (Leonard and Lowe, 1961, p. 124). About 1873 the glacier was said to reach the river, but by 1893 it was about 18 m away (Harper, 1896, p. 307). By 1937 the terminus had receded over 400 m; by 1954, over 800 m; and by 1960, nearly 1600 m (Leonard and Lowe, 1961, p. 124).

The névé of Burton Glacier is steep and broken, and is connected by an icefall to the main glacier, which is fairly level and easy to travel upon. Johannes Glacier was formerly a tributary but has now separated (Leonard and Lowe, 1961, p. 123).

Spa and Azure glaciers have recently shrunk greatly and Callery Glacier at the head of the Callery River, which was about 3 km long in 1891 and 1900, had disappeared by 1951 (Leonard and Lowe, 1961, p. 127).

(b) Waiho River. Franz Josef Glacier "is about 11 km. long and rises in an undulating névé enclosed by mountains rising to 3,048 m. The firn line is at about 2,000 m. while the valley tongue is about 4 km. long and descends a steep and broken ice fall into a deeply entrenched valley" (Gunn, 1964, p. 173).

More is known of the fluctuations of Franz Josef Glacier than of any other glacier in New Zealand. The terminus was photographed in 1865 and 1867, and was surveyed in 1893, 1908, 1914, and 1926 (Harper, 1926, p. 344). Recession has been the rule, interrupted by slight readvances near 1910 (Bell, 1910, p. 5), from the 1920's to 1934, and from 1947 to 1950 (Suggate, 1950, p. 426). Until recently the glacier ended on the

river flats, but lately has begun to withdraw up much steeper slopes. Between 1956 and 1963 the terminus withdrew from 230 m (750 ft.) to 295 m (970 ft.) above sea level (Gunn, 1964, p. 173). In July 1965 the terminus was readvancing (D. B. Lawrence, personal communication).

In 1956 flow rates were measured at several localities on the glacier; the greatest velocity was 245 cm a day. Ablation averaged 8.2 cm a day from January to April at an altitude of 350 meters (1150 ft.) (Gunn, 1964, pp. 178 and 189).

(12) Waikukupa Catchment

Two small glaciers between Fox and Franz Josef glaciers drain into the Waikukupa River.

(13) Cook Catchment

(a) Fox River. Fox Glacier has a total length of 15 km, of which the tongue makes up 8 km. The glacier leaves the accumulation area in an icefall (Gunn, 1964, p. 173). In contrast to Franz Josef Glacier it changed little between 1890 and the late 1930's (Harper, 1934, p. 323; Speight, 1939, p. 59). Between 1935 and 1956 it receded 1000 m and a further 800 m from 1956 to 1963 (Gunn, 1964, p. 176). In 1965 dead, debris-covered ice extended over a kilometer in front of the active terminus but 2 km back the ice had thickened and was advancing into scrub (J. H. Mercer, personal observation), and between May and July 1965 the terminus advanced 10 m (D. B. Lawrence, personal communication).

Movement studies were carried out in 1955 and 1956. Ablation measurements at 350 m (1150 ft.) between January and April gave an average of 8.2 cm a day, the same as on Franz Josef Glacier (Gunn, 1964, pp. 178-179 and 189).

Victoria Glacier was thickly covered by surface moraine for one third of its length in 1894 (Harper, 1896, p. 107). In 1965 debris still covered most of the trunk of the glacier, according to aerial photographs.

(b) Cook River. Balfour and La Perouse glaciers are both about 7 km long. In 1894 Harper (1896, p. 89) observed that the Balfour was mainly a reconstituted glacier, the ice falling over a 300-m cliff: the trunk was entirely debris-covered. There were five stranded lateral moraines, three of which had corresponding terminal moraines (Gunn, 1964, p. 91). The 1965 aerial photographs show a similar state of affairs.

Photographs show that La Perouse Glacier descends in a series of steps to a flattish, debris-covered lower part.

(14) Karangarua Catchment

(a) Copland River. Nine glaciers drain into the Copland River; Strauchon Glacier, the largest, is about 5 km long. Between 1895 and 1913 its terminus remained unchanged, but from 1913 to 1932 it retreated nearly a kilometer despite its heavy debris cover (Harper, 1934, p. 323). The 1965 aerial photographs show that it has thinned greatly since a recent maximum.

In 1894 Marchant Glacier had five stranded lateral moraines and a completely debris-covered trunk (Harper, 1934, p. 323), which had disappeared when the 1965 aerial photographs were taken.

Copland Glacier has a debris-covered reconstituted trunk, and in 1965 it had shrunk greatly from recent moraines.

(b) Douglas River. Nine glaciers drain into the Douglas River. The névé of Douglas Glacier is separated from the trunk by precipices and at the beginning of the century avalanches fell every two minutes on average (Bell, 1908, pp. 126-128). By 1956, according to Odell (1956, p. 454), avalanches no longer fell, which would imply that the tongue was dead ice. The 1965 aerial photographs show the trunk to be completely debris-covered. It has thinned and receded greatly and ends behind a proglacial lake.

Fitzgerald Glacier appears in an 1894 photograph to be a reconstituted glacier. It was much crevassed and debris-covered at the beginning of the century (Bell, 1908, p. 128). (Another Fitzgerald Glacier drains into the Godley River, Waitaki Catchment.)

Horace Walker Glacier is free of surface debris (Harper, 1934, p. 324).

Mount Cook National Park to the Haast Pass Road

The mountains bordering the southwestern boundary of the Mount Cook and Westland national parks carry many glaciers. Summits decrease in height to the southwest and have less ice.

(15) Paringa Catchment

A few small glaciers drain into the Paringa River.

(16) Haast Catchment

(a) Landsborough River. Fourteen named glaciers drain into the Landsborough River. Near the beginning of the century McKerrow Glacier was very crevassed and debris-covered in its lower part and its

front was over 30 m high (Bell, 1908, p. 131). Between 1894 and 1929 it retreated about 350 m (Harper, 1934, p. 324).

Spence, Le Blanc, Beith, and Arthur glaciers were debris-covered; Fettes Glacier carried little debris and reached the river in a wall of ice about 30 m high (Bell, 1908, p. 132). The 1965 aerial photographs show Strachan Glacier terminating above timberline. Ice from the terminus forms a debris-covered avalanche cone far below.

(b) Haast River. Mt. MacFarlane (2523 m, or 8278 ft.) above the right bank of the Haast River just below the Landsborough confluence has small glaciers.

Mt. Brewster (2519 m, or 8264 ft.), 7 km northeast of Haast Pass, has glaciers; Brewster Glacier, the largest, is on the west side.

Haast Pass Road to Fiordland National Park

Southeast of the Haast Pass road summits gradually increase in height, culminating in Mt. Aspiring (3036 m, or 9960 ft.). The isolated Lindsay Glacier drains into the Okuru River. Sixteen kilometers to the southwest small glaciers lie on Mt. Dreadful and along the watershed to Castor and Pollux. Further southwest the mountains are heavily ice-covered for a distance of about 50 km; included in this stretch are the Mt. Aspiring group, the Barrier Range, the Olivine Range, the Forbes Mountains, and the Humboldt Mountains. The named glaciers are distributed as follows:

Waiatoto Catchment	9
Arawata Catchment	17
Cascade Catchment	2
Hollyford Catchment	7
Clutha Catchment	25

The longest glaciers are Volta and Therma (Waiatoto Catchment), Dart and Whitburn (Dart River, Clutha Catchment) and Joe River (Arawata Catchment), each about 5 km long. Photographs show that the névés of most glaciers are steep but an exception is the undulating Olivine Ice Plateau. The ice frequently issues from the névé as an icefall, for example on Therma and Volta glaciers, Mt. Aspiring. Some glacier tongues, such as Snow White, are very clean, but others such as Joe River are completely covered with debris. Both these glaciers drain into the Arawata River.

Fiordland National Park

Glaciers are believed to be confined to the extreme north of Fiordland National Park but small ones may await discovery in central Fiordland, where a few peaks exceed 1800 m (6000 ft.).

The Darran Mountains, culminating in Mt. Tutoko (2756 m, or 9042 ft.), have several glaciers. They are steep and broken, carry little surface debris, and are short; Donne Glacier, the longest, measures about 3 km.

Maps show unnamed glaciers on the Llawrenny Peaks (1963 m, or 6440 ft.), 8 km west of Milford Sound; Jervois Glacier on Mt. Elliott, 5 km north of the highest point on the Milford track; two small unnamed glaciers on Mt. Pyramid (2326 m, or 7630 ft.), the southward continuation of the Darran Mountains; and a glacier on Mt. Pembroke, west of the Darran Mountains. Photographs show the Llawrenny Peaks glaciers and Jervois Glacier to be small ice bodies occupying ledges of moderate slope.

Addendum

At the end of October, 1965, both Fox and Franz Josef glaciers (Cook and Waiho Catchments) were reported to be advancing. Since May the Fox had advanced about 25 m and the Franz Josef 113 m, and both had thickened considerably above their termini (personal communication J. H. Taylor to D. B. Lawrence, forwarded to the author through the courtesy of Dr. Lawrence).

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Note: Many references have also been made throughout the text to isolated photographs appearing in The Canterbury Mountaineer, the New Zealand Alpine Journal, and Tararua (annual of the Tararua Tramping Club). These references are listed in full in the following section, "Photographic Sources."

Other Sources

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Photographic Sources

NORTH ISLAND

Cowan (1927)

Pl. 13.	Wahianoa, Whangaehu, and Mangatoetoenui glaciers.
Pl. 14.	Whangaehu Glacier and crater ice.
Pl. 15.	Mangaehuehu Glacier.

Odell (1955)

Figs. 1, 2, 4, 5, and 7.	Ice on Mt. Ruapehu.

Heine (1962)

Fig. 2.	Whakapapanui and Whakapapaiti glaciers.
Figs. 3-5.	Whakapapanui Glacier, 1960, 1961, and 1962.

SOUTH ISLAND

Note: In summer 1964-65 oblique aerial photographs of 28 glaciers were taken for Dr. D. B. Lawrence, Department of Botany, University of Minnesota. Copies of these are held by Dr. Lawrence in Minneapolis; by World Data Center A: Glaciology, American Geographical Society, New York; and by Dr. Ian McKellar, New Zealand Geological Survey, Dunedin. The following glaciers were photographed: Adams, Balfour, Barlow, Burton, Callery (remnants), Classen, Colin Campbell, Copland, Douglas, Fox, Frances, Franz Josef, Gino Watkins, Godley, Hooker, Horace Walker, Marchant, McKerrow, Mueller, Murchison, La Perouse, South Poerua, Spencer, Strachan, Strauchon, Tasman, Whymper, and Zora.

Arthur's Pass to Mount Cook National Park

(1) Waimakariri Catchment

Haast (1879)

P. 146.	Waimakariri River glaciers.

The Canterbury Mountaineer (1957-58) Vol. 8, No. 27.

P. 56.	White, Marmaduke Dixon, and Davie glaciers.

Arthur's Pass National Park Board (1960)

P. 42. — Cahill Glacier.

P. 66. — Marmaduke Dixon Glacier.

Tararua (1962)

P. 59. — Marmaduke Dixon Glacier [?]

(2) Hokitika Catchment

(a) Whitcombe River

Pascoe (1939)

P. 94. — Wilkinson icefall.

P. 106. — McKenzie icefall.

(3) Rakaia Catchment

Pascoe (1939)

P. 172. — Cronin icefall, Wilberforce River.

Hewitt and Davidson (1954)

P. 64. — Glaciers at head of Mathias River.

(a) Rakaia River

Haast (1879)

P. 129. — Lyell Glacier.

Gage (1951a)

P. 494. — Lyell Glacier, 1949; Ramsay Glacier, 1910 and 1949.

Hewitt and Davidson (1954)

Pp. 66 and 71. — Ramsay Glacier.

The Canterbury Mountaineer (1955-56) Vol. 7, No. 25.

P. 53. — Jagged, Gridiron, and Assault glaciers.

Tararua (1962)

Pp. 38-39. — Lyell Glacier.

(b) Cameron River

Gage (1951b)
P. 139. — Cameron Glacier, 1951.

The Canterbury Mountaineer (1952-53) Vol. 6, No. 22.
P. 81. — Cameron Glacier.

_______ (1956-57) Vol. 7, No. 26.
Cameron Glacier, N branch.

(4) Ashburton Catchment

The Canterbury Mountaineer (1958-59) Vol. 8, No. 28.
P. 127. — Ashburton Glacier.

(6) Wanganui Catchment

Pascoe (1939)
P. 132. — Adams Glacier.

_______ (1940)
Pl. 6. — Beelzebub Glacier.
Pls. 7 and 8. — Adams Glacier.

New Zealand Alpine Journal (1959) Vol. 18, No. 46.
P. 67. — Adams Glacier, 1936 and 1959.

(8) Rangitata Catchment

Hewitt and Davidson (1954)
P. 76. — North Forbes Glacier.

(a) Clyde River

Hewitt and Davidson (1954)
P. 75. — Frances Glacier.

(9) Whataroa Catchment

(a) Perth River

Pascoe (1940)
Pls. 3 and 4. — Perth Glacier.

Hewitt and Davidson (1954)
P. 101. Part of the Garden of Eden ice plateau.

(b) Whataroa River

New Zealand Alpine Journal (1951) Vol. 14, No. 38.
P. 27. Whymper Glacier.

Odell (1956)
Pp. 452-453. Gino Watkins Glacier.

New Zealand Alpine Journal (1961) Vol. 19, No. 48.
P. 135. Wigley Glacier.

Mount Cook and Westland National Parks

(10) Waitaki Catchment

(a) Godley River

Hewitt and Davidson (1954)
P. 78. Easter, Elizabeth, and lower Classen glaciers.
P. 80. Upper Godley Glacier.

The Canterbury Mountaineer (1960-61) Vol. 9, No. 30.
P. 48. Fitzgerald Glacier.

(c) Murchison River

Mannering (1891)
Pp. 90 and 92. Murchison Glacier.
P. 120. Onslow Glacier.

Rose (1937)
P. 456. Murchison and Harper glaciers, 1914 and 1935.

The Canterbury Mountaineer (1952-53) Vol. 6, No. 22.
P. 64. Lower Murchison, Cascade, and Baker glaciers.

New Zealand Alpine Journal (1953) Vol. 15, No. 40.
Pp. 116-117. Murchison, Aida, and Harper glaciers, and small glaciers in the Liebig Range.

(d) Tasman River

Mannering (1891)	
Pp. 28 and 90.	Hochstetter Glacier.
P. 50.	Ball Glacier.
Pp. 54 and 86.	Upper Tasman Glacier.
Fitz Gerald (1896)	
P. 176.	Upper Tasman Glacier.
Bell (1907)	
P. 193.	Upper Tasman Glacier.
Faur (1915)	
Pp. 122 and 148.	Tasman Glacier.
Porter (1926)	
Pl. 5.	Haast, Kaufmann, and Forrest-Ross glaciers.
Pl. 10.	Head of Rudolf Glacier.
Harper (1934)	
P. 322.	Junction of Ball and Tasman glaciers, 1891 and 1934.
Speight (1940)	
P. 134.	Lower Tasman Glacier.
P. 135.	Tasman Glacier terminus.
Harrington (1952)	
P. 131.	Upper Tasman, Malte Brun, and Beetham glaciers.
Walker (1952)	
P. 451.	Hochstetter Glacier.
The Canterbury Mountaineer (1952-53) Vol. 6, No. 22.	
P. 72.	Caroline Glacier.
Shadbolt (1962)	
Pp. 494-495.	Upper Tasman Glacier.
Skinner (1964)	
Figs. 2 and 4.	Lower Tasman Glacier, 1962.

(e) Hooker River

Haast (1879)	
P. 32.	Mueller Glacier terminus; Hooker Glacier.
Mannering (1891)	
P. 10.	Hooker Glacier.
Fitz Gerald (1896)	
Pp. 112, 124, and 198.	Mt. Sefton glaciers.
Pp. 142 and 238.	Upper Hooker Glacier.
P. 314.	Small glaciers on the W side of Hooker Glacier.
Bell (1908)	
P. 129.	Hooker Glacier.
Faur (1915)	
P. 90.	Mueller Glacier.
Porter (1926)	
Pl. 12.	Upper Mueller Glacier.
Walker (1952)	
P. 420.	Hooker Glacier.
Hewitt and Davidson (1954)	
P. 82.	Hooker Glacier.
Kolb (1958)	
Fig. 13.	Hooker and Mueller glaciers.
Figs. 14-16.	Mueller Glacier.
Fig. 18.	Hooker Glacier.

(11) Waiho Catchment

(a) Callery River

New Zealand Alpine Journal (1938) Vol. 7, No. 25.	
P. 250.	Upper Spencer Glacier.
Leonard and Lowe (1961)	
Pp. 116-117.	Upper Spencer Glacier.
P. 135.	Lower Burton, Leonard, Spa, Azure, Styx, Cerberus, Corrie, Montague, and Times glaciers.

New Zealand Alpine Journal (1964) Vol. 20, No. 51.
P. 272. — Montague Glacier.

(b) Waiho River

Haast (1879)
P. 103. — Franz Josef Glacier terminus [drawing from a photograph].

Fitz Gerald (1896)
P. 302. — Franz Josef Glacier névé.

Harper (1896)
Pp. 52, 57, and 75. — Franz Josef Glacier.

Bell (1907)
P. 185. — Franz Josef Glacier.

Harper (1926)
P. 343. — Franz Josef Glacier terminus, about 1907.

New Zealand Alpine Journal (1949)
P. 123. — Franz Josef Glacier terminus, 1945 and 1949.

Suggate (1950)
P. 438. — Franz Josef Glacier terminus, 1948.

Hewitt and Davidson (1954)
Pp. 92-98. — Franz Josef Glacier, several photographs.

Kolb (1958)
Fig. 19. — Franz Josef Glacier.

Odell (1960)
Figs. 1 and 3. — Franz Josef Glacier, about 1867 and 1959.

Gunn (1964)
Fig. 2. — Upper Franz Josef and Almer glaciers.

(12) Waikukupa Catchment

New Zealand Alpine Journal (1939) Vol. 8, No. 26.
P. 8. Fritz Glacier.

(13) Cook Catchment

(a) Fox River

Harper (1896)
Pp. 101 and 104. Fox Glacier.

Bell (1907)
Pp. 191, 195, and 197. Fox Glacier.

Moore (1936)
P. 217. Fox Glacier.

New Zealand Alpine Journal (1952) Vol. 14, No. 39.
P. 294. Victoria Glacier.

Kolb (1958)
Fig. 17. Fox Glacier.

Odell (1960)
P. 744. Fox Glacier terminus, 1955.

Gunn (1964)
Figs. 4,5,9,10, 15,16, and 17. Fox Glacier.

(b) Cook River

Harper (1896)
P. 88. Balfour Glacier.

Porter (1950)
Pl. 25. La Perouse Glacier.

Hewitt and Davidson (1954)
P. 104. Balfour Glacier, 1894.
P. 105. La Perouse Glacier, 1895.

The Canterbury Mountaineer (1956-57) Vol. 7, No. 26.
P. 127. La Perouse Glacier.

(14) Karangarua Catchment

(b) Douglas River

Harper (1896)
P. 235. — Fitzgerald Glacier.
P. 248. — Douglas Glacier.

New Zealand Alpine Journal (1935)
P. 8. — Horace Walker, Morse, Wicks, and Douglas glaciers.

Mount Cook National Park to the Haast Pass Road

(16) Haast Catchment

(a) Landsborough River

Bell (1908)
Pp. 123 and 131. — McKerrow Glacier.

The Canterbury Mountaineer (1958-59) Vol. 8, No. 28.
P. 99. — Zora and Zircon glaciers.

Haast Pass Road to Fiordland National Park

Waiatoto Catchment

Turner (1922)
P. 56. — Mt. Aspiring glaciers.

Gilkison (1951)
Pp. 8-9 — Therma Glacier, 1908.
Pp. 24-25 and 73. — Volta and Therma glaciers.

New Zealand Alpine Journal (1955) Vol. 16, No. 42.
P. 83. — Volta Glacier.

Odell (1956)
Pp. 452-453. — Volta Glacier.

Arawata Catchment

New Zealand Alpine Journal (1934) Vol. 5, No. 21.
P. 314. — Andy Glacier.

New Zealand Alpine Journal (1935) Vol. 6, No. 22.
P. 40 — Joe River Glacier.

______(1939) Vol. 8, No. 26.
P. 50 — Snow White Glacier.

Holloway (1943)
P. 49. — Olivine Ice Plateau and vicinity, three photographs.

Gilkison (1951)
Pp. 24-25 — Bonar Glacier.

New Zealand Alpine Journal (1955) Vol. 16, No. 42.
P. 154. — Joe River Glacier

Clutha Catchment

New Zealand Alpine Journal (1935) Vol. 6, No. 22.
P. 128. — Dart Glacier.
P. 132. — Hobbs, Hesse, Marshall, and Dart glaciers, Dart River.

______(1939) Vol. 8, No. 26.
P. 48. — Upper Whitburn Glacier, Dart River.

Gilkison (1951)
P. 72. — Glaciers on the E side of Mt. Aspiring, Matukituki River drainage.

Hewitt and Davidson (1954)
P. 115. — Glaciers on Mt. Avalanche, Matukituki River drainage.

Odell (1956)
Pp. 452-453. — Kitchener Glacier, Matukituki River.

Gilkison (1957)
Several photographs of glaciers on Mt. Earnslaw, Dart or Rees River drainage.

Fiordland National Park

Turner (1922)
Pp. 226, 232, 252, and 254. — Donne Glacier and others on Mts. Tutoko and Madeline.

Crozier (1950)
P. 33. — Glaciers near Mt. Tutoko, 1922.
P. 49. — Glaciers near Karetai Peak.
P. 65. — Glaciers near Lake Adelaide, 1907.
Pp. 104-105. — Age Glacier, 1917.

Hewitt and Davidson (1954)
P. 125. — Glaciers on Mt. Madeline.

The Canterbury Mountaineer (1954-55) Vol. 6, No. 24.
P. 239. — Glaciers on the Llawrenny Peaks.

New Zealand Alpine Journal (1957) Vol. 17, No. 44.
P. 122. — Korako, Te Puoho, and Age glaciers.

________ (1959) Vol. 18, No. 46.
P. 129. — Age Glacier.

Hall-Jones (1960)
Pp. 16-17. — Jervois Glacier on Mt. Elliot, and a glacier on Mt. Pembroke.
Pp. 32-33. — Glaciers on Mts. Tutoko and Madeline.

New Zealand Alpine Journal (1960) Vol. 18, No. 47.
P. 334. — Upper Donne Glacier.

Map Sources

Harper (1926)
P. 344. [Sketch map of the terminal positions of Franz Josef Glacier in 1893, 1908, 1914, and 1926].

New Zealand Alpine Journal (1949) Vol. 12, Nos. 34 and 35.
Accompanying map. Hopkins, Twain and Landsborough Districts [1:150,000].

McKellar (1955)
P. 222, Fig. 1. Map of the Lower Reaches of the Hooker and Mueller Glaciers, with Stranded Moraine Groups Numbered in Order of Age [1:36,000].

New Zealand Alpine Journal (1957) Vol. 17, No. 44.
Accompanying map. The Darran Mountains, Fiordland, New Zealand [1:80,000].

Kolb (1958)
P. 129. Mueller-Gletscher: Skizze der Moränenwälle [ca. 1:18,000].
P. 132. Hooker-Gletscher: Skizze der Moränenwälle [ca. 1:14,000].
P. 135. Tasman-Gletscher: Skizze der Moränenwälle [ca. 1:4000].
P. 139. Karte der Gletscherstände des Franz Josef-Gletschers [ca. 1:14,000].

The Canterbury Mountaineer (1958-59) Vol. 8, No. 28.
P. 102. [Sketch map showing the area between the upper Landsborough River and Brodrick Pass].

O'Shea (1959)
Fig. 1. The Summit Features of Ruapehu [1:38,000; based on aerial photography].

Odell (1960)
P. 740. Sketch Map of Terminal Face of Franz Josef Glacier, 1946-1959 [1:10,500].

Leonard and Lowe (1961)
Accompanying map. The Headwaters of the Callery, [1:50,000].

New Zealand Department of Lands & Survey, Wellington. Map of Westland and Mount Cook National Parks, N.Z.M.S. 180, [1:100,000, 2nd ed., 1961].

Goldthwait and McKellar (1962)
Fig. 1. Tasman Glaciological Observations [1:170,000].
Fig. 2. Map of Tasman Glacier Névé [1:150,000].

New Zealand Department of Lands & Survey, Wellington. Map of Fiordland National Park, N.Z.M.S. 122, [1:300,000], 3rd ed., 1962.

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Accompanying map. The Olivine Country [ca. 1:126,720].

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19 Haast [1965].

GLACIERS OF
THE SUB-ANTARCTIC ISLANDS

GLACIERS OF
THE SUB-ANTARCTIC ISLANDS

The Sub-Antarctic islands may be defined as those lying between the southern limit of trees and the Antarctic continental shelf. Moving eastward from the Greenwich meridian, those carrying glaciers are: Bouvetøya, Kerguelen, Heard Island, Balleny Islands, Scott Island, Peter I Island, South Orkney Islands, South Georgia, and South Sandwich Islands. All lie south of the Antarctic convergence except Kerguelen, which is a short distance to the north. Île de la Possession also lies north of the convergence and is included here because, although ice-free, it was until recently believed to carry glaciers.

Bouvetøya

Bouvetøya (54°26'S, 3°24'E) is a single volcanic cone with a wide, indented crater and rising into two low peaks, the higher reaching 935 m. Photographs show that the eastern side of the island is entirely covered in ice that reaches the coast on a broad front. The northern and western sides are steeper and freer from ice. Holtedahl (1929, p. 94) believed that the firn limit was rather above sea level, and in 1955 a South African expedition found less snow and ice than had Holtedahl (Polar Record, 1956, p. 256).

Photographs show that the surface of the icefield is smooth and of low gradient over much of the eastern part of the island. The western glaciers are very crevassed and descend to the sea in a series of icefalls; Posadowskybreen flows north and Christensenbreen flows south.

A comparison of the photographs of Christensenbreen and vicinity on the south coast in 1899 (Sachse, 1925, Pl. 7) and 1929 (Holtedahl, 1929, Pl. 50) reveals no visible change in the ice cover in the 30-year interval. On the east coast, rock exposure appears to have increased slightly between 1899 (Sachse, 1925, Pl. 8) and 1955 (Polar Record, 1956, p. 256).

Île de la Possession

Île de la Possession (46°23'S, 51°37'E) is the largest and highest of the Crozet Group. When first seen in January 1772 the island was snow-covered, but when visited by H.M.S. Challenger in January 1874 was entirely snow-free (Thomson and Murray, 1885, p. 322). Its height was then estimated at 1500 m and although Thomson and Murray (1885, p. 318) insisted that this might be considerably in error on account of weather conditions at the time, it was accepted until recently and encouraged the belief that the island reached above the snowline and must support at least small glaciers (Klebelsberg, 1949, p. 568; Flint, 1957, p. 435).

Tilman (1960, p. 394), who climbed to the highest point, estimated it to be only about 960 m by aneroid, and snow and rime that covered the summit at the time had all disappeared in a few days. A later French expedition also found no permanent snow or ice (Faure, 1962, p. 29). A recent figure for the maximum height is only 800 m (Admiralty, 1961, p. 268).

Île de Kerguelen

Île de Kerguelen is about 100 km both north to south and east to west, and centered on latitude 49°20'S and longitude 69°30'E. It is the main island of the Kerguelen archipelago and contains all the glaciers. They are concentrated in the west and south and consist of an icefield and several groups of mountain glaciers.

The glaciers were little studied till very recently. Several were visited by the Deutsche Südpolar Expedition in 1902 and observations were made on glacier morphology and the altitude of the snowline (Werth, 1921, pp. 115-126). Du Baty (1922, p. 116) made two visits in 1908-09 and 1913-14 and published a map showing the approximate positions of many glacier fronts. De la Rue (1932) visited Kerguelen twice between 1928 and 1931 and has described the glaciers. In 1952-53 and 1956-57 the island was again visited by French parties who studied the Péninsule Courbet and early in 1960 a small British party ascended the icefield, named Cook Glacier.

In summer 1961-62 the Terres Australes et Antarctiques Françaises (TAAF) began a program of intensive study of the ice cover: this program was approved by the Comité National Français de Recherches Antarctiques (CNFRA). A long and exacting study was planned, to be carried out in three phases: (1) a reconnaissance map and qualitative observations such as glacier type, altitude of the firn limit, and approximate annual accumulation; (2) a mosaic of aerial photographs of the ice-covered areas and the precise photogrammetric determination of the positions of the glacier fronts and of the velocity at the fronts; (3) determination of the mass balance, meteorological observations, and a study of the ancient moraines. The first phase was carried out in summer 1961-62 (Bauer, 1963a, p. 3). In the course of this work, almost all the glaciers were photographed and four maps on a scale of about 1:100,000 were made, giving the glacier outlines. In January 1963, 1109 vertical aerial photographs, covering 60 percent of the glaciers, were made (Bauer, 1963b).

The glaciers are in four main groups: Presqu'île de la Société de Géographie, Cook Glacier and environs, Presqu'île Rallier du Baty, and Mont Ross.

The Presqu'île de la Société de Géographie is very rugged, with sharp peaks and ridges and many individual glaciers that are active and

have relatively stationary termini (Bauer, 1963a, p. 5). Photographs show a moderate debris cover near the glacier termini. Nine glaciers are shown on the map, the longest being Du Mulon Glacier, 4 km long. De la Rue (1932, p. 36) reported that a Paul Lemoine Glacier reached sea level in the Baie de l'Illustration: no glacier is within 1.5 km of the sea today and the identity of this glacier is uncertain.

Cook Glacier is an icefield of about 500 sq. km, reaching about 1100 m above sea level. It is dome-shaped and the western side is steeper than the others. The surface is very crevassed in the ablation area and lower parts of the accumulation area. The firn limit varies from place to place between 600 m and 900 m and the glacier is temperate in type (Bauer, 1963a, p. 6). The upper part of the névé is "a level expanse of uncrevassed snow" (Tilman, 1960, p. 396).

Recession, probably of Dumont d'Urville Glacier, was noted when the German ship Gazelle called during her voyage of 1874-76, and in 1928 and 1931 glaciers on the eastern side of the icefield were in marked retreat but the western tongues showed fewer signs of recession (de la Rue, 1932, p. 184).

The recent survey has given the following picture of the icefield. On the northern side, glaciers descend in icefalls. On the west they are all very active, especially Curie and Pasteur glaciers which are the only ones in Kerguelen that calve into the sea: none show any signs of retreat (Bauer, 1963a, pp. 6-7). In photographs, many of the eastern glaciers appear to have fairly gentle gradients but are much crevassed near the termini. On both the northern and eastern sides, many glaciers end in proglacial lakes (Bauer, 1963a). Naumann Glacier on the eastern side was photographed in 1960 (Tilman, 1965, p. 395) and 1962 (Bauer, 1963a, Figs. 13 and 15). A great break-up of the tongue in the proglacial lake occurred in the two-year interval, the fragments still retaining their original relative positions.

The glaciers in the Presqu'île Rallier du Baty have many icefalls and carry a heavy load of rock waste in their lower parts, so that great expanses of ice-cored moraine lie in the terminal areas. Brunhes Glacier on the west side just fails to reach tidewater (Bauer, 1963a, p. 9).

Many glaciers lie on the peaks between the Presqu'île Rallier du Baty and Cook Glacier; they were not photographed in 1961-62 because of bad flying conditions (Bauer, 1963a, p. 5).

Mont Ross, about 2000 m high, is the highest point in the island and carries many cirque and hanging glaciers. Some avalanche-fed glaciers are completely hidden by rock waste in their lower parts. In the huge crater on the eastern side, avalanche-fed Buffon Glacier reaches the sea in debris-covered cliffs but does not calve (Bauer, 1963a, p. 10).

In 1902 small cirque glaciers lay on Mt. Crozier, Mt. Werth, and Mt. Wyville-Thomson in the Péninsule Courbet (Werth, 1921, p. 125). In 1928 and 1931 the northwest and southeast slopes of Mt. Crozier held several very small glaciers, and on the south side of Mt. Werth was the small Gazert Glacier (de la Rue, 1932, pp. 37-38). In 1953 Mt. du Château held three small ice remnants which had disappeared by 1957, when only six glaciers remained in the peninsula: two each on Mts. Werth, Crozier, and Amery. They had shrunk greatly since the beginning of the century and the only one still receiving alimentation was Sicaud Glacier on the northeast side of Mt. Werth (de la Rue, 1958, p. 7). By 1962 the glaciers on Mt. Werth and Mt. Crozier had disappeared (Bauer, 1963a, p. 5).

Heard Island

Heard Island (53°06'S, 73°31'E) is situated about 150 km south of the Antarctic convergence, and consists of a volcanic cone 18 km across with a long shingle spit to the east and a secondary volcanic peninsula to the northwest. Big Ben, the main volcanic cone, culminates in Mawson Peak, 2745 m high. Volcanic activity is confined to vapor emission from Mawson Peak and occasionally from lower vents. The island is nine tenths ice-covered, and more than half the coast consists of ice cliffs (Budd, 1964, p. 2).

The weather is extremely bad: average annual temperature at sea level is 0.5°C and precipitation falls on 300 days (Budd, 1964, p. 3). Clear days occur about once a month on average, the remainder of the time being cloudy with frequent storms (Law and Béchervaise, 1957, pp. 76 and 78). Snow often falls at sea level during the summer, but rain has been experienced at 1200 m and thaw conditions at 2300 m (Budd, 1964, pp. 24-25). Graphic descriptions of the weather experienced by parties on Big Ben are given by Deacon (1963) and Budd (1964).

The first scientific knowledge of the island resulted from the visit of H.M.S. Challenger in February, 1874. The extent of snow-free ice was very small and the glaciers in Corinthian Bay, which had recently thinned, terminated on the beach (Thomson and Murray, 1885, pp. 371-372). The same part of the island was visited in 1902 by the German Gauss expedition. Photographs were taken of Baudissin Glacier and the north coast glaciers were described (Drygalski, 1904, pp. 213-217; 1908, pp. 231-239).

De la Rue, who visited the island in 1929, reported that Cape Gazert was the only ice-free part of the west coast. In this part of the island the glacier surfaces were remarkably smooth, being crevassed only near the sea (de la Rue, 1930, p. 27).

After the establishment of the Australian base in 1947, some studies were made of the glaciers. Lambeth (1951) concluded that they were shrinking, and Mellor (1959, p. 232), who estimated the firn limit as 300 m, found a vegetation trimline 30 m above the surface of Baudissin Glacier. The base was abandoned in 1954.

In early 1963 after an attempt on Mawson Peak, an Australian party travelled round the coast from Long Beach in the south anticlockwise to Atlas Cove in the northwest, and found much evidence for glacier recession. Fifty-One Glacier was easy to cross; Winston Glacier had retreated several hundred meters since 1954 and had become much less of an obstacle; and on the north coast Stephenson and Brown glaciers, which had ended in sea cliffs in 1954, had receded, forming a lagoon and shingle beach. Compton Glacier had also receded and a beach was starting to form; the surface, which had been smooth in 1954, was now crevassed. Downes, Challenger, and Baudissin glaciers were also badly crevassed (Budd, 1964, pp. 32-40).

Balleny Islands

The Balleny Islands (66°30'S, 163°E) lie northwest of Cape Adare and about 260 km from the Antarctic coast. They are volcanic in origin, and volcanic activity was reported on Buckle Island by Balleny in 1839 and again by Borchgrevink's expedition in 1899. None has been noted since. The islands are heavily ice-covered, and ice tongues may project a mile or more seaward (Admiralty, 1961, pp. 361-363).

Young Island is about 30 km by 8 km and reaches an altitude of about 1000 m. Most of the island is a gently sloping ice-covered plateau. Steep rocky bluffs form much of the coastline, but in places glaciers come down to the sea.

Row Island is only about 800 m long and reaches 180 m altitude. It is mostly ice-covered.

Borradaile Island is about 3 km by 1.5 km and 380 m high. It is covered by a flat-lying glacier cap, ending in ice cliffs above rock precipices.

Buckle Island, about 20 km by 4 km and 945 m high, consists of an ice-covered plateau from which glaciers descend steeply to form long ice cliffs in the sea. Much of the coast is steep and ice-free.

Sturge Island is 27 km by 9.5 km (Admiralty, 1961, p. 361), and reaches 1158 m. Steep rocky cliffs are interrupted by broad ice tongues from the interior.

Scott Island
(67°24'S, 179°55'W)

Scott Island is about 800 m by 400 m and is of volcanic origin. The cliffs on the north are precipitous and about 40 m high, but in the south they are only about 2 m high. The highest point is 54 m. In 1902 according to Colbeck (1905, p. 404), the north end of the island was almost bare and the southern end was lower and partly ice-covered. Recently the island has been described as completely ice-covered (U.S. Navy Hydrographic Office, 1960, p. 223; Admiralty, 1961, p. 363) but photographs suggest that Colbeck's description was more accurate.

Peter I Island
(68°50'S, 90°35'W)

Peter I Island is oblong in shape and about 24 km by 8 km, longest in a north-south direction. The central part of the east coast is precipitous, but the western side is less steep. The northern and southern parts of the island are low. The rounded dome of Lars Christensen Peak, the highest point (1753 m), is an ice-filled extinct crater.

In 1929 members of the second Norvegia expedition circumnavigated the island and landed on the west coast. All parts of the island of sufficient flatness were seen to be ice-covered, showing that the snowline was at sea level (Holtedahl, 1929, p. 88). Since 1948 landings have been made by Norwegians, Americans, and Russians. In February 1960 the U.S.S. Burton Island circumnavigated the island several times and found it to be considerably shorter in a north-south direction than formerly believed, and also over 500 m higher (Bulletin of the U.S. Antarctic Projects Officer, 1960).

South Orkney Islands

The South Orkney group consists of islands of all shapes and sizes, lying between 43°20'W to 46°50'W and 60°30'S to 60°45'S. The most important are Coronation, Laurie, Powell, Signy, and Fredriksen. The Scottish National Antarctic Expedition in 1901-03 studied the ice cover of Laurie Island and produced a descriptive account (Pirie, 1913). For the group as a whole, the description and photographic coverage by Marr (1935) is still by far the most complete; a shorter and more accessible account with many of the same photographs is John (1934).

On average, the climate is continental from April to November because of surrounding pack ice and oceanic for the remainder of the year, but the time of arrival of the pack ice varies from year to year. The coldest

month averages about -10°C (14°F) and the warmest about 0°C (32°F). Cloudiness is high and fog frequent (Marr, 1935, pp. 344-345).

All the islands except Signy rise abruptly from the sea, the maximum elevation being 1266 meters in the center of Coronation Island. The ice cover is similar in type to that in the Antarctic Peninsula: short glaciers, sloping gently near the coasts but steepening rapidly against the inland ridges, and ending in ice cliffs (Marr, 1935, p. 336).

Travel is often easy on the gentle slopes near the coast but is greatly hindered by the intervening rock cliffs. Inland, conditions are difficult; John (1934, p. 393) has described the huge crevasses and seracs that frustrated an attempt to climb Sandefjord Peak on Coronation Island.

Two morphological types of ice cover predominate: "highland" or plateau ice and ice piedmonts. The highland ice covers the higher parts of the islands that have moderate slopes, and the ice piedmonts start in the valleys below and end along the coast. In places the two types merge into one another (Marr, 1935, p. 360).

The western end of Coronation Island has a smooth cover of highland ice that in places reaches the coast in long, low ice cliffs and elsewhere spills over the steep coast in icefalls. In the east, highland ice merges with ice piedmonts (Marr, 1935, p. 361), the largest of which is Sunshine Glacier on the south coast.

The western third of Laurie Island consists of mountainous peninsulas with serrated peaks. Ice piedmonts fill the valleys at the heads of the bays, a few of them interconnected but most separated by the steep cliffs. The remainder of the island has a nearly continuous covering of highland ice, broken by several nunataks (Pirie, 1913, p. 838; U.S. Navy Hydrographic Office, 1943, p. 71).

Powell Island is steep and high and mostly ice-covered. At the southern end the ice surface sweeps down smoothly to sea level, in places ending in ice cliffs. At the northern end, masses of broken ice cling to the steep mountainsides (Marr, 1935, p. 363 and Pl. 23).

Signy Island reaches only 240 m in height and carries comparatively little ice. Most of the southern half is covered by McLeod Glacier, a thin, smooth icefield with many nunataks, but in the north where the terrain is more irregular, the ice is in isolated patches. The major outlet from the southern icefield is a steep ice tongue that ends several hundred meters inland from the southern end of Borge Bay; stranded moraines show that this glacier formerly reached the sea. Most of the coastline is ice-free (Marr, 1935, p. 362).

Fredriksen Island carries some permanent snow but little ice. Much of the largest of the Larsen Islands is covered by ice of low gradient but most of the coastal cliffs are ice-free. Christoffersen and Saddle islands also carry considerable ice and one of the Inaccessible Islands has a small capping of ice. A comparison of photographs of Saddle Island taken in 1903 and 1933 shows no visible change in the ice cover in the 30-year interval (Pirie, 1913, Pl. 9, Fig. 1; Marr, 1935, Pl. 25, Fig. 3).

South Georgia

South Georgia, lying between 53°55'S and 54°55'S, and 35°40'W and 38°25'W, is about 160 km long and 32 km wide. It is mountainous, reaching 2934 m, and very rugged. About 56 percent of its area is ice-covered and half of the remainder is steep rock above the snowline (Smith, 1958, p. 6).

The climate is very stormy and oceanic; at sea level snow may fall in midsummer and rain in midwinter. Gales are frequent, especially in spring and autumn, and the rare calm days are usually foggy (Chaplin, 1932, p. 342). Sutton (1957) and Carse (1959) give many graphic descriptions of the appalling weather high up in the interior of the island, and also good accounts of sledging and traveling conditions. Sutton's photographs show rugged peaks protruding above glaciers much broken up by icefalls and crevasse fields, but containing snowfields on which travel on skis was possible.

According to Holtedahl (1929, p. 81), the glaciers of South Georgia are typically much wider than long. On the northeast side are many short, fairly flat valley glaciers heading in steep cirques.

In 1882-83 the German expedition observing the transit of Venus repeatedly surveyed the calving front of Ross Glacier. On each occasion the front was further back (Vogel, 1885, p. 83). By 1902 the front had readvanced 1 km (Nordenskjöld, 1905, p. 345). It was surveyed about 1920 (Filchner, 1922, p. 110) but the results are not known to have been published. In 1955 it had receded to an intermediate position (Brown, 1956).

As part of the United Kingdom's International Geophysical Year program, Hodges and Harker glaciers near Grytviken were studied but Hodges Glacier was found to be too large for systematic investigations. In various parts of the island observations were made on the firn limit, which was found to be highest (500 m) near Grytviken and lowest (250 m) on the west coast between Undine South Harbour and Cape Disappointment (Smith, 1958, p. 7; 1960, p. 708). All the glaciers below about 1000 m were thought to be temperate in type.

Every glacier visited had a series of moraines in front of it with immature vegetation, pointing to recession during the past century. Smith

claimed that a comparison of photographs taken in 1914 [probably in Wordie, 1921, Pl. 2, Fig. 2] and 1957 showed that Hamberg and Harker glaciers had advanced several hundred meters but Nordenskjöld Glacier had retreated about 100 m. A glacier west of Leith Harbour, the only noncalving glacier with records, had thinned and receded since 1912 (Smith, 1958, p. 9). Movement studies of Harker Glacier showed 2 m a day near the terminus and 1.75 m a day further up. Hamberg Glacier moved 0.8 m a day near the center of the terminus (Stansbury, 1961, p. 36).

South Sandwich Islands

The South Sandwich Islands lie between 56°18'S and 59°28'S and 26°14'W to 28°11'W. All are of volcanic origin and many are active volcanoes. Most of the islands are heavily ice-covered but volcanic heat is believed to be responsible for keeping parts of some islands snow-free. The most complete description remains that of Kemp and Nelson (1932).

Zavodovski Island appears to be continuously active and the western side, where the activity is concentrated, is steep and largely snow-free (Kemp and Nelson, 1932, Pl. 13, Fig. 3). Ice cover on the eastern side of the cone is smooth in outline without conspicuous icefalls and terminates at a snow-free plateau extending along the southern and eastern sides of the island (Kemp and Nelson, 1932, p. 150, and Pl. 13, Figs. 1 and 2). A recent photograph of the ice cover on the southeast side of the island shows similar conditions (Ivanov, 1959a, p. 37). According to Holdgate (1963, p. 402) the island is much more irregular in outline than the charts suggest.

Leskov Island has no ice cover and little permanent snow (Kemp and Nelson, 1932, p. 150).

Visokoi Island, an active volcanic cone, is almost entirely ice-covered except for some cliffs and headlands. The ice descends to sea level but in most places is separated from water by a narrow morainal beach. Below the snowline the ice was covered in black volcanic ash in 1930 and was heavily crevassed (Kemp and Nelson, 1932, p. 164, and Pl. 15, Figs. 2 and 3). The chart of the island is essentially correct, according to Holdgate (1963, p. 402).

The southern part of Candlemas Island is completely ice-covered but the northern part, consisting of a lava plateau and two active volcanic cones, carries no permanent snow (Kemp and Nelson, 1932, p. 150). The ice reaches the sea in only a few places (p. 169) and the highest point of the island is at about 550 m (Holdgate, 1963, p. 401). Photographs of the ice cover show no rock outcrops, and in 1930 parts were apparently covered with volcanic ash (Kemp and Nelson, 1932, Pl. 17, Figs. 1 and 2; Holdgate, 1963, p. 401). According to Holdgate (1963, p. 401) the island is very imperfectly charted, especially in the active northern part.

Vindication Island has a small, thin ice cap from which two glaciers flow to the sea. Much of the island is ice-free (Kemp and Nelson, 1932, p. 170 and Pl. 18, Fig. 3).

Most of Saunders Island consists of an ice-covered volcanic cone 805 m high. Considerable crevassing is visible on the upper slopes, and the lower slopes are blackened by volcanic ash (Kemp and Nelson, 1932, p. 173, and Pl. 20, Fig. 1). The ice reaches sea level but appears to terminate in ice cliffs behind a narrow morainal beach (Kemp and Nelson, 1932, Pl. 21, Fig. 2). The southeastern part of the island is ice-free, and consists of a group of extinct craters (Kemp and Nelson, 1932, Pl. 20, and Pl. 21, Figs. 1 and 2).

Montagu Island, about 1350 m high, is the largest in the group and the most heavily ice-covered. Patches of bare ground and signs of melting on and near a subsidiary peak in the southeast are the only signs of vulcanism. The ice in places ends above steep, rocky cliffs, and elsewhere reaches sea level. On the east side of the island a vertical ice face runs without interruption for 8 km (Kemp and Nelson, 1932, pp. 150 and 175). On the north and west sides steep and broken glaciers reach the sea (Kemp and Nelson, 1932, Pl. 23, Figs. 2 and 3). In a recent visit a landing was made (Ivanov, 1959b).

Bristol Island has very heavy ice cover extending to the coast in every direction. On the east side of the island and also to the west of the northernmost point the ice reaches the sea in cliffs; on the east side they are over 5 km long and in places over 60 m high. Elsewhere the ice ends in a vertical face above rock cliffs (Kemp and Nelson, 1932, p. 177, and Pl. 25, Figs. 1-3). Kemp and Nelson (1932, p. 150) believed Bristol Island to be inactive, but Mt. Darnley (1100 m), the central peak, erupted in 1935 and another vent that breaks through the ice cap above the western point of the island erupted in 1956. The coastline is believed to be very different from that shown on the charts (Holdgate, 1963, p. 400).

Bellingshausen Island is an active volcano with a wide crater reaching 160 m. The steep eastern and northern sides are almost snow-free, but the south and west sides have large patches of permanent snow (Kemp and Nelson, 1932, p. 183, and Pl. 28; Polar Record, 1965a, p. 421).

Cook Island has three ice-capped peaks, the highest reaching about 1050 m (Holdgate, 1963, p. 398). It is almost entirely ice-covered except for the steeper parts of the coast. Eight glaciers reach the sea, the largest being 800 m wide. Icefalls and heavily crevassed areas are common (Kemp and Nelson, 1932, p. 185, and Pls. 29 and 30).

Thule Island is mostly ice-covered, with rather uniform ice slopes extending up to the summit plateau at 820 m. The southeast peninsula is ice-free (Holdgate, 1963, p. 398, and photo p. 400). In most places round the coast the ice breaks off abruptly above steep cliffs, but in places glaciers reach the water's edge. Conspicuous dirt bands are visible in some sections (Kemp and Nelson, 1932, p. 187, and Pls. 30 and 31). The island was formerly believed to be inactive, but recently a steaming crater with ice cliffs around the edge was seen from the air, and quantities of black ash lie on the ice in the southwestern part of the island (Holdgate, 1963, p. 398, and photo p. 401).

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U. S. Navy Hydrographic Office (1960)

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Hatherton (1964)

P. 427.	Part of Borradaile Island; Sabrina Islet.

<u>Anon.</u> (1965b)

Five photographs of islands, including both of those in Hatherton (1964).

<u>Scott Island</u>

Colbeck (1905)

P. 402.	[The best photograph of the island.]

U. S. Navy Hydrographic Office (1943)

P. 184.

________ (1960)

P. 377.	[Same photo as U. S. Navy Hydrographic Office (1943), but less well printed.]

Peter I Island

Holtedahl (1929)	
Pls. 41-45.	Thirteen photographs, covering all coasts except the N.
_______ (1931)	
P. 404.	Part of W coast [same as in Holtedahl, (1929)].
U. S. Navy Hydrographic Office (1943)	
P. 171.	SW side; N point.
_______ (1960)	
P. 375.	[Same photo as U. S. Navy Hydrographic Office (1943), but less well printed.]

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Pls. 3-8 and 11.	Laurie Island, 1903.
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John (1934) [All of these photographs also appear in Marr, 1935.]	
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Pl. 18, Figs. 1-3.	Coronation Island, N side.
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Figs. 2-3.	Powell Island.
Pl. 23, Fig. 1.	Fredriksen Island.
Figs. 2-3.	Laurie Island.
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U. S. Navy Hydrographic Office (1943) [All of these photographs also appear in Marr, 1935.]

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Sutton (1957)	Apart from the photographs of the icefields of the interior mentioned in the text:
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_______ and Nelson (1932)
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Ivanov (1959a)
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Holdgate (1963)
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P. 421. — Bellingshausen Island.

Map Sources

Bouvetøya

Anon. (1956)
P. 257. — Bouvetøya [1:150,000; based on South African Hydrographic Office, 1956.]

South African Hydrographic Office, Cape Town. Bouvet Øya, S.A. 1, 1:48,000, 1956.

Île de Kerguelen

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Map 1. — Presqu'île de la Société de Géographie. Geographie.
Map 2. — Glacier Cook.
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Heard Island

Budd (1964)
Accompanying map. — Heard Island, Australian Territory, 1:50,000. [Shaded relief map published by the Division of National Mapping, Department of National Development, Canberra.]

Balleny Islands

Hatherton, Dawson, and Kinsky (1965)
Fig. 1. — The Balleny Islands and Their Geographical Location [1:380,000]. [Shows Young, Borradaile, and Buckle Islands with contours; also includes an inset map of the group, scale ca. 1:1,200,000.]

Anon. (1965b)
P. 432. — [Same map as Hatherton, Dawson, and Kinsky, 1965, Fig. 1, except that it is reduced in size.]

Scott Island

U. S. Navy Hydrographic Office, Washington. Scott Island and approaches, H.O. 6668, 1:100,000, 2nd ed., 1962. [Includes inset map: Scott Island, 1:15,000.]

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U. S. Navy Hydrographic Office, Washington, Eights Coast and George Bryan Coast, H.O. 6713, 1:500,000, 1961. [Includes inset map: Peter I Island, 1:250,000.]

South Orkney Islands

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South Orkney Islands: West Sheet, 1963. [Shows Coronation and Signy Islands; the East Sheet, showing Lauri Island, was not published by August 1965.]

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South Georgia, 1958.

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Pls. 11, 12, 14, 16, 19, 22, 24, and 27. [Outline charts of all the islands, with inaccuracies as noted by Holdgate, 1963. Scales vary from 1:52,000 to 1:83,000.]

Accompanying map. South Sandwich Islands, Chart No. 3593, 1:500,000. [Published by the Admiralty, London, 1930.]

Admiralty, London. South Sandwich Islands, Chart No. 3593, 1:500,000, 1930. [Same as Kemp and Nelson, 1932, accompanying map, but with corrections to 1955.]

MOUNTAIN GLACIERS OF ANTARCTICA

MOUNTAINS GLACIERS OF ANTARCTICA

The greater part of Antarctica is covered by an ice sheet, and mountain glaciers are of restricted occurrence. In West Antarctica they occur in the Antarctic Peninsula and in several well-separated mountain groups; in East Antarctica, throughout the Transantarctic Mountains and in mountain ranges within 300 km of the coast, mostly in Queen Maud Land and Enderby Land. Outlet glaciers flowing through the mountains from the ice sheet are included in this discussion, but ice streams within the ice sheet are not.

Mountain glaciers of all morphological types occur, including highland ice; summit, valley, cirque, and crater glaciers; glaciers on slopes; and ice piedmonts. Because many mountain ranges are uplifted peneplains, highland ice is abundant.

According to Ahlmann's classification, all the glaciers are geophysically polar or subpolar except in the northern part of the Antarctic Peninsula where they are temperate, at least at low altitudes. Because the equilibrium line is at or near sea level, large glaciers calve into the sea either directly or by merging into shelf ice. At all latitudes, however, some small glaciers end on land, or as inset glaciers. They may be outlets from the ice sheet or distributary tongues from valley glaciers, but most are independent cirque glaciers. Near the coast, ablation on these glaciers may be partly or mainly by melting, but in the interior is a type of glacier peculiar to Antarctica, where ablation is entirely by evaporation. Most of the glaciological investigations in Antarctica have been on the ice sheet and the ice shelves but studies on the regimen of these independent glaciers might give valuable information.

Accumulation and movement studies have been carried out in the South Shetland Islands and the northernmost Antarctic Peninsula. Movement studies have also been made on several glaciers joining the Ross Ice Shelf and on glaciers in south Victoria Land and the Sør-Rondane Mountains. Elsewhere only descriptive information is available about the mountain glaciers. Known glacier variations have been summarized by Mercer (1962).

Glaciers of West Antarctica

(1) Antarctic Peninsula and Offshore Islands

The Antarctic Peninsula extends from about 63°S to near 74°S. North of 69°S it is narrow and mountainous; to the south it broadens and south of about 74°S the ice cover merges with the ice sheet of West Antarctica.

Robin and Adie (1964, p. 104) have described the ice cover of the peninsula as follows: "Over the greater part of its length the central plateau area of the narrow peninsula reaches a height of over 2,000 m. From this ice-capped plateau, valley glaciers descend comparatively steeply to the west and east coasts, and consequently the majority of them are fast-flowing . . . ." Many of the west coast glaciers are severely crevassed in their upper parts, and the east coast glaciers give better access to the plateau. This may be because of the higher precipitation on the western side.

The contrast between the west and east coasts has been described by Linton (1963, p. 277). In a 70-km traverse of Louis Philippe Peninsula [Trinity Peninsula] one passes "from an area of relatively heavy precipitation with all the lower relief features blanketed without trace beneath the névé . . . to a region starved of snow, where only relict ice masses are to be found in exclusively lowland situations and even the discharge of the plateau ice caps may not reach the sea."

The equilibrium line lies below 150 m on the west coast, at 300 m at Hope Bay, and over 300 m in Prince Gustav Channel and the west side of James Ross Island. Much rime is deposited on the west coast glaciers, particularly on steep faces. In itself it adds little to the accumulation, but it effectively binds the snow and cuts down drifting (Koerner, 1961, pp. 1068 and 1072).

Ice piedmonts, which Fleming (1940, p. 93) termed "fringing glaciers," occur throughout the whole west coast of the peninsula where shelf ice is not present, and also on the east coast. They lie between the base of the mountain cliffs and the shore as a belt of low-lying glacial ice, truncated on their seaward side by ice cliffs, usually between 25 m and 30 m high. Their width varies between a few meters and several kilometers.

The peninsula contains the transition zone between temperate and polar glaciers, which is close to the northern limit of shelf ice. According to Robin and Adie (1964, p. 105), all measurements made so far show that shelf ice is polar or subpolar. "It is probable that sub-polar glaciers on land reach sea level somewhat north of the point where ice shelves can exist. The boundary is likely to be very sensitive to climatic changes and measurements are now being made to determine its position on the west coast of Graham Land [Antarctic Peninsula], with the aim of tracing future changes in its position." The northern limit of shelf ice is near 64°S on the east coast, and near 69°S on the west coast. At about 68°S, the 10-m firn temperature is at or near 0°C at sea level on the west coast and -16°C at 2000 m.

Thus, compared to the east coast, the west coast has a lower equilibrium line and heavier land ice because of greater precipitation, but has less shelf ice because of higher temperatures.

Between 1957 and 1960, Depot Glacier near Hope Bay station (63°24'S, 56°59'W) was studied by members of the Falkland Islands Dependencies Survey (Koerner, 1964, p. 9 et seq.). This is a valley glacier 3430 m long and 800 to 900 m wide, calving into Hope Bay. From year to year, ablation varied most in spring and autumn; summers were more uniform, and meltwater streams flowed on the surface for about two weeks. Superimposed ice formed during föhn conditions in winter, and during one such period (July 1958) a temperature of 14°C (57°F) was registered, the maximum recorded temperature for the Antarctic continent. The calving front was sketched in 1903, and in 1945 was in about the same position; from 1945 to 1960 it receded 75 to 90 m. The surface movement averaged 7 to 8 cm a day. The Mt. Flora cirque glacier near by has three stranded moraines in front of it, two of them ice-cored.

The ice piedmont between Hope Bay and Trepassey Bay was also studied (Koerner, 1964, p. 23 et seq.). Its gently sloping surface extends from 400 m above sea level down to ice cliffs 30 m high. Most of the glacier is below the firn limit at 300 m, but because of superimposed ice, the equilibrium line is lower. Slush flows occur during the melting season and sometimes during midwinter under föhn conditions. The glacier is probably near equilibrium, and has changed little since photographed in 1903. Its activity is low and Koerner believes it is relict.

Russell East Glacier originates in a broad and level névé on the Louis-Philippe Trinity and descends in two icefalls. It is 11 km long and averages 1.75 km wide (Koerner, 1964, p. 5), and moves at about 50 cm a day (Koerner, 1964, p. 21).

Glaciers on King George Island in the South Shetlands near 62°S were studied between 1957 and 1960. Stenhouse Glacier is a fast, highly crevassed outlet of the island's extensive icecap, and Flagstaff Glacier is a cirque glacier near by. The glaciers are temperate throughout, even at 800 m on the icecap. Mean monthly temperatures are usually above freezing point in December through February and thawing may take place at sea level in any month. A 10-m pit was dug on the icecap, and a tentative interpretation of annual layering suggested an annual accumulation of the order of 100 cm of water a year, but with considerable year-to-year variation (Noble, 1958?, Fig. 4, p. 7).

Stenhouse Glacier advanced 120 m between 1957 and 1960 (Stansbury, 1961, p. 43), but this does not necessarily mean greater activity for the position of the calving front may depend far more on sea temperature than on the glacier regimen (Noble, 1958?, p. 16).

Flagstaff Glacier has a very negative regimen (Noble, 1958?, p. 16), and usually only about one fifth of the glacier surface is above the firn limit (Stansbury, 1961, p. 41).

A valley glacier on Livingston Island, South Shetlands, moves at about 20 cm a day (Hobbs, 1959, quoted by Koerner, 1964, p. 21).

(2) Mountains South of the Antarctic Peninsula

The Ellsworth Mountains comprise the Sentinel and Heritage ranges and act as a partial barrier to the ice of the West Antarctic Ice Sheet flowing toward the Filchner Ice Shelf. Vinson Massif (5140 m) is the highest mountain in Antarctica. According to Craddock and others (1964, p. 159):

> Almost all the ice passing through the mountains is carried in three great streams -- Newcomer Glacier in the northern Sentinel Range, Minnesota Glacier and its tributaries between the ranges, and Bastien Glacier and its tributaries in the central Heritage Range. Smaller but significant valley glaciers head in the Ellsworth Mountains, only a few flow westward for short distances before being deflected and incorporated in the eastward drainage. The major glaciers of the eastern Sentinel Range all bend sharply at the foot of the mountains and form a distinct south-eastward-moving ice stream.
>
> Locally, extensive systems of large crevasses occur, particularly along escarpments on the west edge of the mountains and on the large valley glaciers and through-flowing ice streams. Wide-spread crevassing in the glaciers of the eastern Sentinel Range make surface travel in that area very difficult. Crevasses as wide as 40 ft. (12 m) occur in Bastien Glacier and depths of 95 ft. (29 m) have been measured in Minnesota Glacier. Little is known about the flow rate of these glaciers but a stake system was established in the 1962-63 season across Minnesota Glacier. The yet unreduced field measurements indicate a detectable movement, of the order of a few feet, of some stakes over a six-week period.

The extinct volcanic cones of the Executive Committee Range contain crater glaciers. The ice-filled craters of Mt. Hampton and Mt. Cummings are unbreached, but on Mt. Sidley, Parks Glacier flows out through a large gap in the crater wall (Hoinkes, 1961, Pl. 59).

The Edsel Ford Ranges acts as a partial dam to the ice of the Rockefeller Plateau. Some valleys contain thin, slow-moving glaciers of local origin (Wade, 1937, pp. 596-597).

Glaciers of East Antarctica

(1) Transantarctic Mountains

The Transantarctic Mountains may be divided into three sections, of increasing effectiveness as a barrier to the ice sheet of East Antarctica: (a) south of the Weddell Sea from the Theron Mountains to Reedy Glacier, only isolated mountain groups are exposed, between which broad expanses of ice flow from East Antarctica to West Antarctica; (b) from Reedy Glacier to Minna Bluff, which approximately comprises the mountains facing the Ross Ice Shelf, several powerful but confined outlet glaciers flow from the ice sheet to the Ross Ice Shelf; and (c) from Minna Bluff to Cape Adare where the mountains face McMurdo Sound and the Ross Sea, little ice from the plateau flows through the mountains, particularly in the southern section.

(a) Theron Mts. to Reedy Glacier. The Dufek Massif in the Pensacola Mountains has two small plateau glaciers from which outlet glaciers descend to join the main ice sheet. Elsewhere in the massif are many small valley glaciers heading in cirques. Most of these join the ice sheet, but a few discrete glaciers terminate in ice-free valleys, as do some small outlet glaciers from the ice sheet (Aughenbaugh, 1958, pp. 183 and 186).

The Ohio Range rises 1500 m above the ice sheet of West Antarctica. A small glacier lies on the flat summit of Mt. Schopf (2990 m) and glaciers descend on all sides to merge with the surrounding ice. At the southwestern end of the mountain three small glaciers heading in cirques are unconnected with the summit glacier (Mercer, 1963, p. 1).

The Wisconsin Range (3610 m) consists of ice-covered plateaus with some maturely dissected mountains round the periphery. Many steep outlet glaciers from the plateau descend the escarpment. Along the escarpment facing Reedy Glacier are several small discrete glaciers heading in cirques, and with their termini inset into nearly stagnant blue-ice areas of Reedy Glacier. During a period of 60 days (10 Nov. 1964 to 10 Jan. 1965) 6 cm of ice evaporated from a blue-ice area of Reedy Glacier (Mercer, personal observation).

(b) Reedy Glacier to Minna Bluff. From Reedy Glacier to Minna Bluff the Transantarctic Mountains rise directly above the Ross Ice Shelf. Several peaks exceed 4000 m. In ice-free areas on the west side of Reedy Glacier, in the Queen Maud Mountains, several small glaciers end on land. They show no signs of shrinkage and may be advancing (Mercer, personal observation).

Many glaciers in the Queen Maud Mountains are entirely or mainly of local origin. Dendritic mountain glaciers are tributary to the outlet

glaciers or merge independently with the ice shelf (Gould, 1940, p. 858). Some cirque glaciers also exist (Gould, 1939, Fig. 6). The larger local glaciers are very steep compared to the glaciers flowing through the range: Axel Heiberg Glacier, for example, in a series of spectacular icefalls drops 2400 m in 30 km, mostly in 13 km. This glacier is sheltered from the wind and deep snow lies on the surface (Herbert, 1963, p. 399).

Eight large glaciers drain ice from the Polar Plateau through the mountains to the Ross Ice Shelf. These are: Reedy, Robert Scott, Amundsen, Shackleton, Beardmore, Nimrod, Byrd, and Mulock. Other glaciers drain small areas of the plateau but originate mainly in the mountains. Between 1960 and 1962 the flow rates of all these glaciers except Reedy and Shackleton were measured over a 12-month interval (Swithinbank, 1964, Fig. 3, p. 47).

Glacier	Maximum velocity, m/day
Byrd	2.3
Beardmore	1
Mulock	1
Nimrod	0.7
Robert Scott	0.7
Amundsen	0.6

Photogrammetric measurements in 1960-61 gave a very similar result for Byrd Glacier (Brandenberger, 1963). This glacier has been described as "like an ocean in torment. As far as the eye could see, serrate ridges and giant furrows were aligned parallel with the abrupt rock walls of the valley. Between them lay endless fields of crevasses." Even those glaciers that are relatively crevasse-free in the middle have a crevassed zone in a shallow depression 2 to 3 km wide at each margin (Swithinbank, 1964, pp. 35 and 37).

Between Beardmore and Nimrod glaciers, many dendritic mountain glaciers lie in the Queen Alexandra and Queen Elizabeth ranges. Snowfall may be heavy in this area; one meter fell from November 1959 to January 1960 (Gunn and Walcott, 1962, p. 409). Some discrete cirque glaciers exist, ending in debris-covered areas of the main glaciers (Grindley, 1963, Fig. 11).

Little or no Polar Plateau ice reaches the Ross Ice Shelf through Skelton Glacier, whose névé is separated from the Plateau by a depression. Where the glacier joins the Ross Ice Shelf its thickness is between 490 m and 600 m. Where it is afloat, Skelton Glacier seems to move as a solid block with a nearly constant velocity averaging about 90 m per year (Wilson and Crary, 1961, pp. 875-876).

(c) Minna Bluff to Cape Adare. The glaciers from Minna Bluff to Mawson Glacier have been described by Gunn and Warren (1962, pp. 30-41). Outlet glaciers are Ferrar, Wright Upper, Taylor, Mackay, and Mawson. Ferrar Glacier is 100 km long and 5 km wide at the terminus, and is derived partly from the Polar Plateau. Wright Upper Glacier is a lobe of ice about 7 km by 3 km, fed by several icefalls from the Polar Plateau.

Taylor Glacier, about 80 km by 5 km, ends in debris-free cliffs, 15 m to 45 m high. Rock material is scarce on or in the ice, but nearly horizontal shear planes low down at the snout carry silt. The ice is strongly foliated. Rocks on the surface a third of the way across the glacier moved 90 m in three years (Hamilton and Hayes, 1961, pp. 206-207).

Mackay Glacier is 80 km long, excluding 5 km of floating ice tongue. The ice descends from the Polar Plateau in a series of steps probably caused by sills, and there are many crevasse fields, especially in the north. Mawson Glacier is 100 km long excluding the 25-km-long Nordenskjöld Ice Tongue.

Alpine glaciers are very numerous. Koettlitz Glacier is 85 km long; the lower 40 km is believed to be afloat (Gunn and Warren, 1962, p. 39). Hobbs and Davis glaciers west of Cape Chocolate and Canada Glacier in Taylor Dry Valley end in ice cliffs; a comparison of photographs shows that neither these nor Taylor Glacier changed appreciably between 1911 and 1957 (Péwé and Church, 1962, pp. 300-304).

Blue Glacier is 55 km long and reaches McMurdo Sound. It has a very large accumulation area but is rather thin and may move only a meter a year (Gunn and Warren, 1962, p. 39).

In summer 1961-62 some studies were made of four glaciers in the Victoria Valley system: Victoria Lower, Victoria Upper, Webb, and Packard (Calkin, 1964, pp. 8-11). Victoria Lower Glacier flows west from the Wilson Piedmont Glacier and moved at a maximum velocity of 6 mm a day over an 83-day period. Victoria Upper Glacier has an area of over 80 sq. km and ends in a cliffed margin about 60 m high. A velocity of about 3 mm a day was measured. Webb Glacier is 31 sq. km in area, 7 km long and has a very low gradient. It is nearly stagnant and at 775 m the surface lowered about 6.6 cm in 65 days. Packard Glacier is 6.5 sq. km in area and ends in cliffs 41 m high. It is more active than the other glaciers and measurements over a period of several weeks suggest a velocity of 16 m a year above 1000 m. Probably none of these glaciers have retreated significantly in recent years.

Benson Glacier is about 43 km long. Eight kilometers from the sea it splits into two distributaries that descend steep icefalls (Gunn and Warren, 1962, p. 37).

Fry Glacier is about 45 km long, and joins smaller glaciers near its terminus to form a floating tongue 7 km long (Gunn and Warren, 1962, p. 37).

Farther north, outlet glaciers from the ice sheet flow through the mountains to the Ross Sea. Mawson, David, Reeves, Priestley, and Campbell glaciers are all over 100 km long (Ricker, 1964, p. 266). Reeves Glacier has been described as a broad, steep icefall over a diabase barrier, at a point where the Transantarctic Mountains are narrower than anywhere else in their whole length (Harrington, 1963, p. 46).

North of Terra Nova Bay are several outlet glaciers, each "a truly mighty stream of ice" (Harrington, 1963, p. 46). Tucker Glacier, 18 km wide and of gentle gradient, provides easier access to the Polar Plateau than any other major valley glacier in Victoria Land (Harrington, 1963, p. 41). The glaciers in this area have been described by Priestley (1923, pp. 11-23).

The largest glacier in north Victoria Land is the Rennick, flowing along the east side of the Arctic Institute Range.

(2) Glaciers of East Antarctica (Except for the Transantarctic Mountains)

A short distance northwest of Rennick Glacier terminus are the Wilson Hills. Pryor, Suvorov, and Matusevich glaciers are outlets from the ice sheet flowing through these hills. Further west, mountain glaciers are rare or absent for 90 degrees of longitude, as far as the mountains near Lambert Glacier.

In the Mawson Escarpment rising above the east side of Lambert Glacier are large and small outlet glaciers, and glaciers heading in cirques (Crohn, 1959, Pls. 36 and 37). In the Prince Charles Mountains (2438 m) on the west side of Lambert Glacier are small outlets from the ice sheet, and independent valley and cirque glaciers. Some of these glaciers end on land (Crohn, 1959, Pls. 27 and 35). Lambert Glacier itself is about 400 km long and 50 to 100 km broad (Trail, 1964, p. 145).

In the Masson Range just south of Mawson, a small outlet of the ice sheet ends on land, in an ice cliff 12 m high. The bottom meter contains much rock debris (Crohn, 1959, p. 47 and Pls. 15-16).

The Queen Fabiola [or Yamato] Mountains consist of seven massifs separated by outlet glaciers (Yoshida, 1961, p. 4). They reach 2410 m but rise only a few hundred meters above the ice. Several cirque glaciers lie in the mountains; the surfaces of two are entirely blue ice, but others have accumulation areas. Bergschrunds are absent (Yoshida and Fujiwara, 1963, p. 2). Photographs show that some cirque glaciers end on land and others are inset into the main ice (Yoshida, 1961, photos Nos. 2, 3, 6, 7, and 9; Derom, 1961?, pp. 3-5).

The Sør-Rondane Mountains (3625 m) extend westward for 250 km, acting as a partial barrier to the ice sheet. They rise about 1000 m above the ice. Fifteen major glaciers cut through the range which also supports local glaciers in the form of small glacier caps, and alpine, cirque, and niche glaciers (Autenboer, 1964, pp. 41-47). Movement and thickness studies were carried out on five glaciers: the fastest was Gunnestadbreen, 1513 m thick, which moved a maximum of 10.5 cm a day (40 m a year); the slowest was Jenningsbreen, about 1200 m thick, which moved a maximum of 0.2 cm a day (7 m a year) (Autenboer and Blacklock, 1964, pp. 15-16).

In New Schwabenland, mountains extend westward for about 500 km the Wohlthat Mountains in the east and the Mühlig-Hofmann Mountains in the center. Glaciers flow through the Wohlthat Mountains from the ice sheet, and German photographs taken in 1939 (Schytt, 1961, Pl. 7) and recent Russian photographs (Bardin, 1964, p. 20) show small cirque glaciers inset onto debris-covered areas of the main ice. The ice margins appear to have been stable in recent decades (Bardin, 1964, p. 24).

Steep glaciers up to several kilometers wide fall 1000 m as they flow through the Fimbulheimen section of the Mühlig-Hofmann Mountains. Most of the local glaciers have very small accumulation areas and the glaciers on the plateau remnants are thin and almost stationary (Lunde, 1961, p. 7). The mountains closer to Maudheim also have thin local glacier caps (Schytt, 1961, Pl. 12b).

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Photographic Sources

Since World War II most of the Antarctic mountains have been photographed from the air. The United States has covered the Transantarctic Mountains and the mountains of West Antarctica except the Antarctic Peninsula. The photographs are held by the U. S. Geological Survey, Washington, D. C. Great Britain has photographed the Antarctic Peninsula; Australia, the mountains near the Lambert Glacier; Belgium, the Queen Fabiola and Belgica mountains; Norway, the Belgica, Sør Rondane, and Mühlig-Hofmann mountains and other mountains of New Schwabenland; and the USSR, some of the mountains of New Schwabenland.

Photographs from the ground have been made since the end of the nineteenth century. The following is a representative selection.

Glaciers of West Antarctica

(1) Antarctic Peninsula and Offshore Islands

Arctowski (1908) — Glaciers bordering Gerlache Strait, end of the nineteenth century.

Gourdon (1909?)
Charcot (1910)
Nordenskjöld (1920)
Joerg (1936)
Fleming (1940)
Stephenson and Fleming (1940)
Ronne (1948)
Mason (1950)
Fuchs (1951)

Polar Record (1958)
Facing pp. 30 and 31.
Koerner (1961)
Linton (1963)
Priestley and others (1964)

(2) Mountains South of the Antarctic Peninsula

Wade (1937) — Edsel Ford Range.
Hoinkes (1961) — Ellsworth Mountains and Executive Committee Range.

Thiel (1961)
P. 338. — Ellsworth Mountains and nunataks to the S.

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Glaciers of East Antarctica

(1) Transantarctic Mountains

(a) Theron Mts. to Reedy Glacier

Aughenbaugh (1958)	Dufek Massif.
_______ (1961)	Dufek Massif.
Hoinkes (1961)	Wisconsin Range.
Long (1961)	Horlick Mountains.
Stephenson (1961) P. 1164.	Shackleton Range.
Mercer (1963)	Horlick Mountains.

(b) Reedy Glacier to Minna Bluff

Wright (1923) P. 5.	Beardmore Glacier.
Gould (1931)	Queen Maud Mountains.
Blackburn (1937)	Robert Scott Glacier.
Gould (1939)	Queen Maud Mountains.
_______ (1940)	Queen Maud Mountains.
Gunn and Walcott (1962)	Nimrod Glacier.
Grindley (1963)	Beardmore Glacier.
Herbert (1963)	Axel Heiberg Glacier.
Laird (1963)	Nimrod Glacier.
Swithinbank (1964)	Robert Scott, Liv, Beardmore, and Byrd glaciers.

(c) Minna Bluff to Cape Adare

Ferrar and Prior (1907)	
David and Priestley (1914)	
Taylor (1922)	
Priestley (1923)	Victoria Land.
Webb and McKelvey (1959)	Dry valleys.
Harrington and Speden (1960) P. 652.	Dry valleys.
Péwé (1961)	Dry valleys.
Bull and others (1962)	Dry valleys.
Gunn and Warren (1962)	Mawson to Mulock glaciers.
Péwé and Church (1962)	Dry valleys.
Polar Record (1962) Facing p. 58.	Commonwealth Glacier.
Gunn (1963a)	Mt. Erebus Glacier
_______ (1963b)	Dry valleys.
Harrington (1963)	North Victoria Land.
Calkin (1964)	Dry valleys.

Glaciers of East Antarctica

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_______ (1963b)	Dry valleys.
Harrington (1963)	North Victoria Land.
Calkin (1964)	Dry valleys.

(2) Glaciers of East Antarctica (Except for the Transantarctic Mountains)

Schytt (1954)	Mountains of New Schwabenland.
_______ (1958)	
Crohn (1959)	Prince Charles Mountains; Masson, Mawson, and David ranges; and Napier Mountains.
Swithinbank (1959a)	
_______ (1959b)	
_______ (1960)	Mountains of New Schwabenland.
De Breuck (1961)	Queen Fabiola and Sør Rondane mountains.
Schytt (1961)	Mountains of New Schwabenland.
Yoshida (1961)	Queen Fabiola Mountains.
_______ and Fujiwara (1963)	Queen Fabiola Mountains.
Autenboer (1964)	Sør Rondane Mountains.
Bardin (1964)	Wohlthat Mountains.
Trail (1964)	Prince Charles Mountains.

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Map Sources

American Geographical Society, New York. Antarctica, 1:3,000,000, 1962. [In four sheets.]

________. Antarctica, 1:5,000,000, 1965. [Includes inset map: McMurdo Sound, Victoria Land, 1:1,000,000.]

Glaciers of West Antarctica

(1) Antarctic Peninsula and Offshore Islands

Directorate of Overseas Surveys, London. British Antarctic Territory, D.O.S. 710, 1:500,000. [When completed, this series will consist of 20 sheets, covering the Antarctic Peninsula.]

Falkland Islands Dependencies [after 1962 renamed British Antarctic Territory], D.O.S. 610, 1:200,000. [The sheets of this series cover the Antarctic Peninsula.]

(2) Mountains South of the Antarctic Peninsula

U. S. Geological Survey, Washington. Antarctica Reconnaissance Series, 1:250,000.

Newcomer Glacier, 1961.
Nimitz Glacier, 1961.
Vinson Massif, 1961.
Mount Hampton, 1960.
Mount Sidley, 1960.

Glaciers of East Antarctica

(1) Transantarctic Mountains

U. S. Geological Survey, Washington. Antarctica Reconnaissance Series, 1:250,000.

Thiel Mountains, 1959.
Ohio Range, 1959.
Long Hills, 1960.

[Continuation of the same series, using a numbering system:]

ST 57-60/1	Convoy Range, 1962.
ST 57-60/2	Franklin Island, 1962.
ST 57-60/5	Taylor Glacier, 1962.

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ST 57-60/5	Taylor Glacier, 1962.

ST 57-60/6	Ross Island, 1962.
ST 57-60/9	Mount Harmsworth, 1963.
ST 57-60/10	Mount Discovery, 1962.

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SS 56-58, 4	Tucker Glacier, 1960. [Single
SS 59-61, 1	sheet.]
ST 54-57, 15	Westhaven Nunatak, provisional ed., 1961.
ST 54-57, 16	Darwin Glacier, provisional ed., 1961.
ST 58-61, 1	Granite Harbour, 1961.
ST 58-61, 5	McMurdo Sound, 1961.
ST 58-61, 9	Mt. Discovery, provisional ed., 1961.
SU 53-57, 4	Byrd Glacier, provisional ed., 1961.
SU 58-62, 9	Shackleton Inlet, provisional ed., 1961.
SU 58-62, 13	Mt. Miller, provisional ed., 1961.
SU 58-62, 14	Mt. Hope, provisional ed., 1961.
SV 51-50, 4	The Cloudmaker, 1964.

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Herbert (1963)
P. 410. Queen Maud Range, 1:1,267,000; Axel Heiberg Glacier Region, 1:316,800.

Geology of the Tucker Glacier Area, Victoria Land, Antarctica, 1:250,000, 1963. [Physical map with geological information; base data from N.Z.M.S. 166.]

U. S. Geological Survey, Washington. Northern Victoria Land, Antarctica: Sketch map, 1:500,000, 1963.

(2) Glaciers of East Antarctica (Except for the Transantarctic Mountains)

Norsk Polarinstitutt, Oslo. Dronning Maud Land: Fotografer-ingsflyginger 1951-52, 1:1,500,000 [1952?].

______. Dronning Maud Land: Fotogrammetriske Stasjoner 1951, 1:1,000,000 [1952?]

Swithinbank (1955)
Fig. 1. Western Dronning Maud Land [1:2,500,000; published by the Royal Geographical Society, London].

Norsk Polarinstitutt, Oslo. Dronning Maud Land: Sør Rondane, 1:250,000, 1957. [Shows the area from 71°27'S to 72°30'S and 21°15'E to 27°40'E.]

Crohn (1959) [Maps published by the Bureau of Mineral Resources, Geology and Geophysics, Canberra.]
Pl. 1. Antarctica, Amundsen Bay to Vestfold Hills, 1:2,000,000.
Pl. 3. King Edward VIII Gulf to Mawson, 1:500,000.
Pl. 5. Prince Charles Mountains, 1:500,000. [Geological sketch map.]

Institut Géographique Militaire, Brussels. Belgian Antarctic Expedition 1957-1958: Monts Belgica, 1:50,000, 1959.

Yoshida (1961)
Fig. 2. Geomorphic Map of Yamato Mountains, 1:100,000. [Published by the Japanese Antarctic Research Expedition, 1961.]

Norsk Polarinstitutt, Oslo. Dronning Maud Land, 1:250,000.
F 5 Maudheimvidda Giaeverryggen: 1962.
F 6 Borgmassivet, Maudheimvidda, 1962.
F 7 Kirwanveggen, Maudheimvidda, 1962.
G 5 Ahlmannryggen, Maudheimvidda, 1962.
G 6 Jutulstraumen, Maudheimvidda, 1961.
G 7 Neumayerskarvet, Maudheimvidda, 1961.
H 5 Fimbulheimen Jutulgryta: 1961.
H 6 H. U. Sverdrupfjella, Fimbulheimen, 1961.
J 6 Mühlig-Hofmannfjella Sör, Fimbulheimen, 1962.

K 6	Filchnerfjella Sör, Fimbulheimen, 1962.
L 6	Glopeflya, Fimbulheimen, 1964.
M 6	Hoelfjella Sör, Fimbulheimen, 1964.

Division of National Mapping, Canberra. Australian Antarctic Territory, Enderby Land, 1:250,000.

SQ 38-39/11	Mount Riiser-Larsen, 1963.
SQ 38-39/12 & 8	Mount Codrington & Proclamation Island, 1964.
SQ 38-39/14	Tange Promontory, 1962.
SQ 38-39/15	Simpson Peak, 1962.
SQ 38-39/16	McLeod Nunataks, 1964.

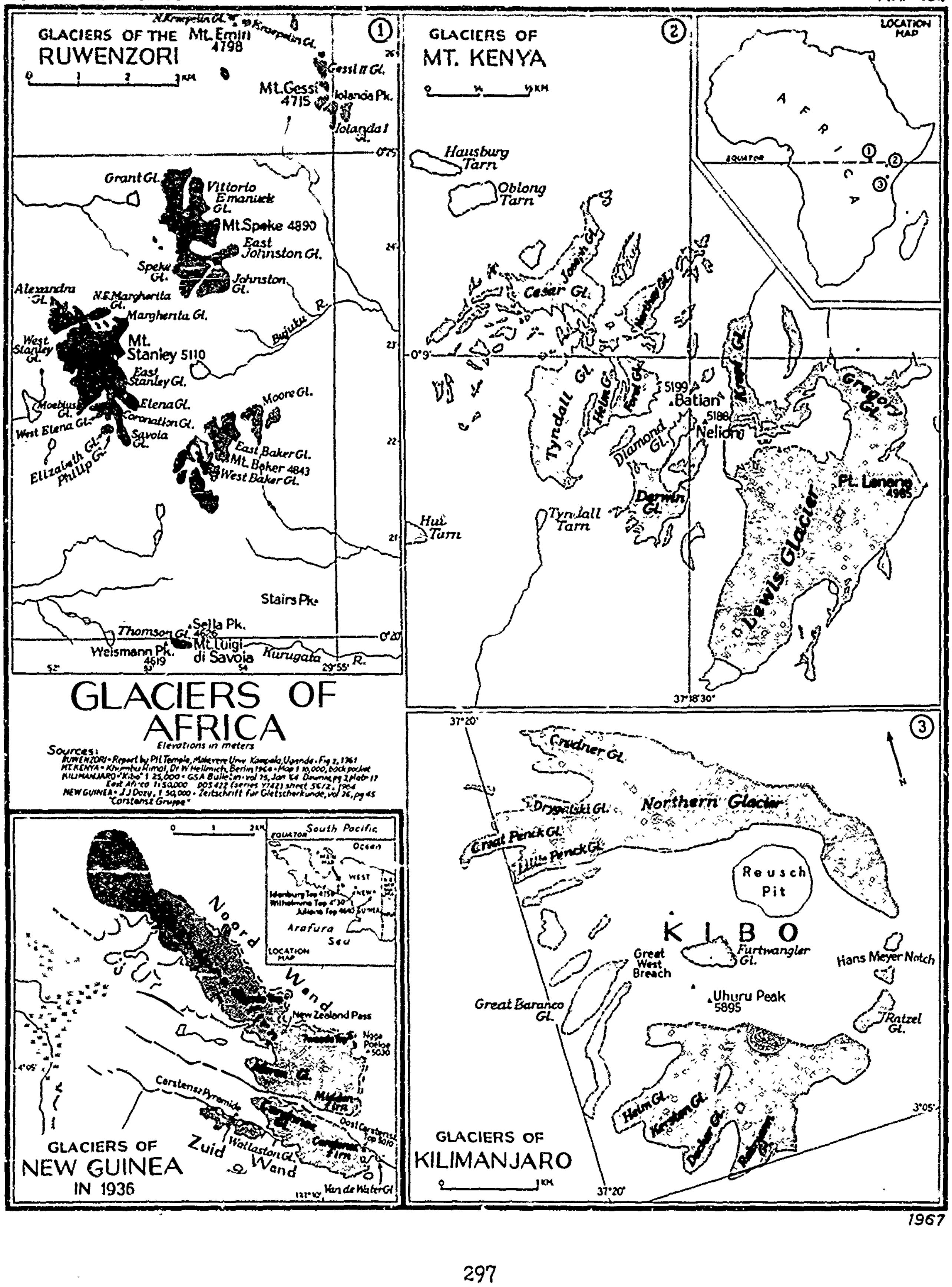
______. Australian Antarctic Territory, Mac-Robertson Land: Framnes Mountains, 1:100,000, 1963.

______. [Australian Antarctic Territory], 1:100,000.

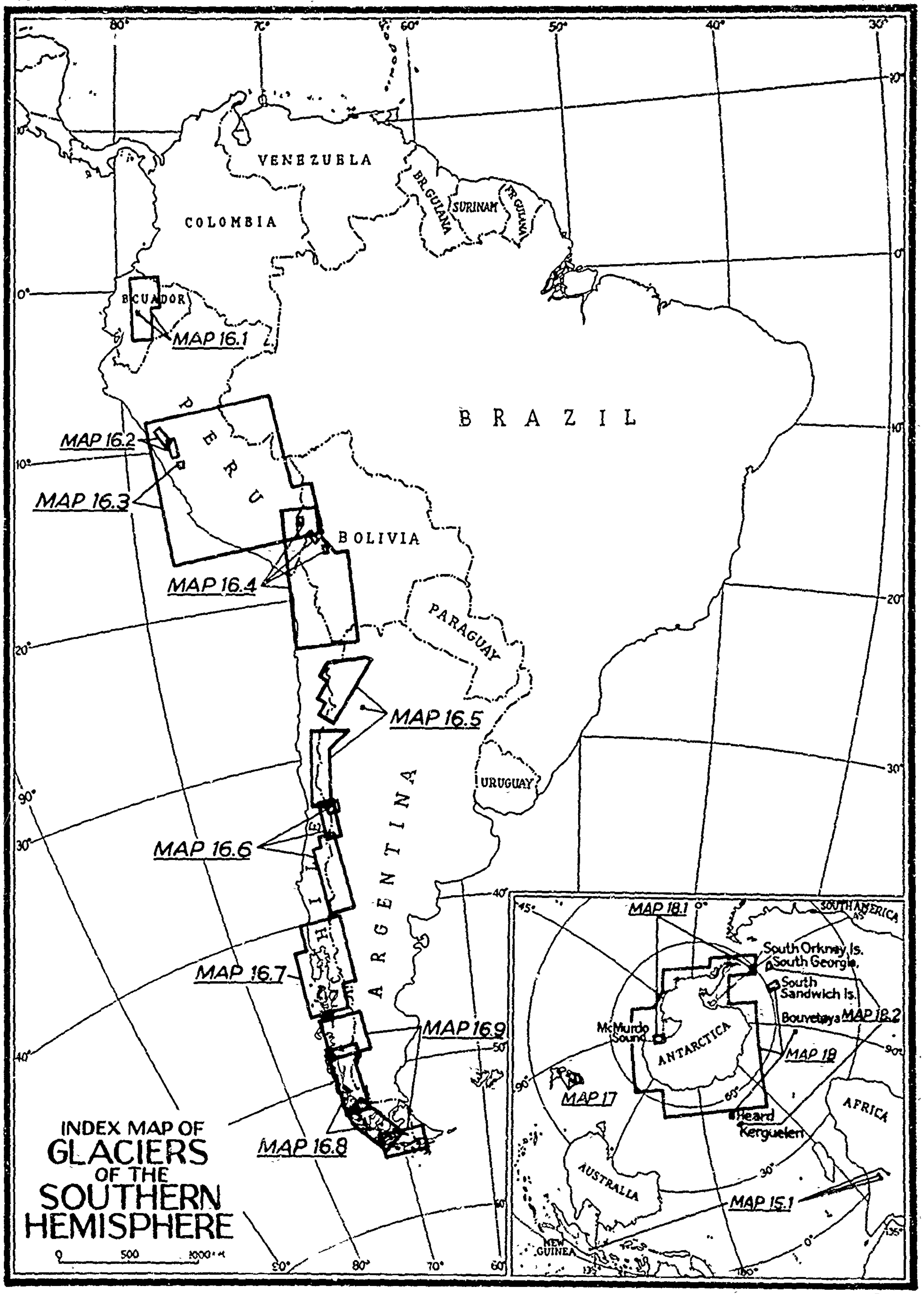
SQ 40-41/15	Mawson, preliminary ed., 1963.

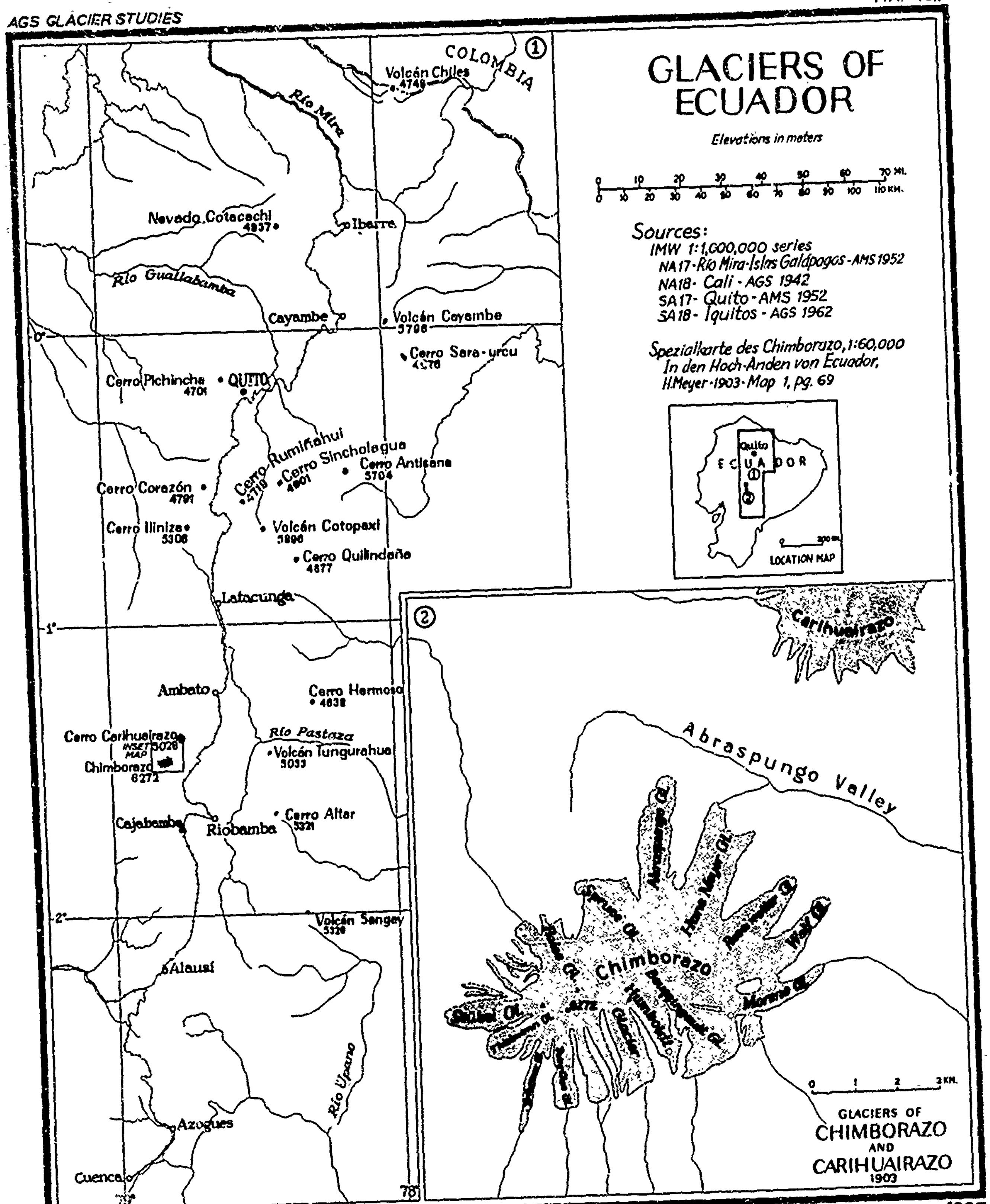
Institut Géographique Militaire, Brussels. Third Belgian Antarctic Expedition 1959-1960, Operation Iris: Belgica Mountains, 1:25,000, 1963.

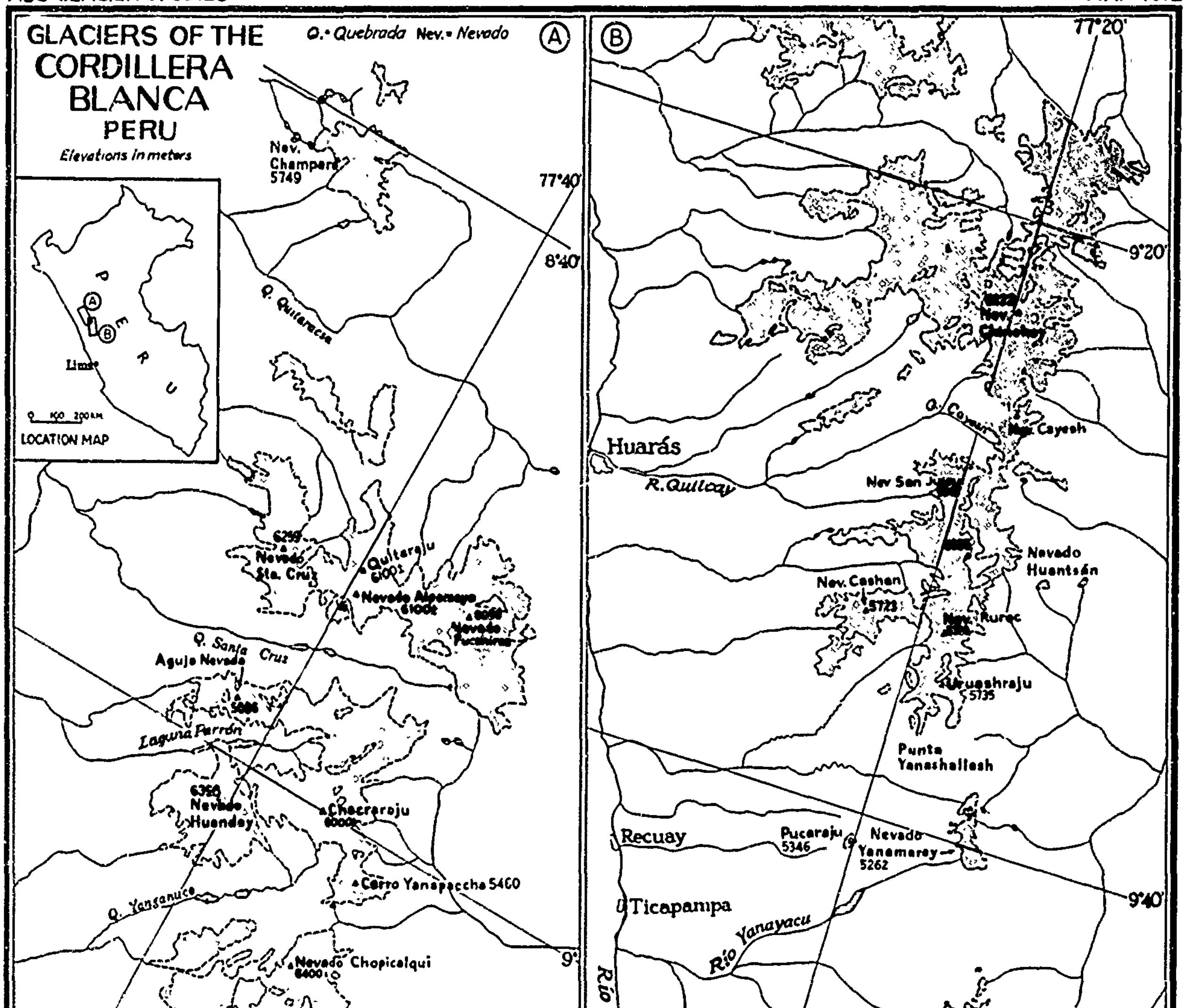
MAP 15.1


GLACIERS OF THE RUWENZORI
Mt. Emin 4798
Mt. Gessi 4715
Iolanda Pk.
Grant Gl.
Vittorio Emanuele Gl.
Mt. Speke 4890
East Johnston Gl.
Speke Gl.
Johnston Gl.
Alexandra Gl.
Margherita Gl.
Mt. Stanley 5110
East Stanley Gl.
Elena Gl.
Coronation Gl.
West Elena Gl.
Savoia Gl.
Elizabeth Gl.
Phillip Gl.
Moore Gl.
East Baker Gl.
Mt. Baker 4843
West Baker Gl.
Stairs Pk.
Thomson Gl.
Sella Pk. 4626
Weismann Pk. 4619
Mt. Luigi di Savoia
Kurugata R.
GLACIERS OF MT. KENYA
Hausburg Tarn
Oblong Tarn
Cesar Gl.
Joseph Gl.
Tyndall Gl.
Heim Gl.
Batian 5199
Nelion 5188
Diamond Gl.
Darwin Gl.
Gregory Gl.
Lewis Glacier
Pt. Lenana 4985
Tyndall Tarn
Hut Tarn
LOCATION MAP
AFRICA
EQUATOR
GLACIERS OF AFRICA
Elevations in meters
GLACIERS OF KILIMANJARO
Credner Gl.
Drygalski Gl.
Northern Glacier
Great Penck Gl.
Little Penck Gl.
Reusch Pit
KIBO
Great West Breach
Furtwangler Gl.
Hans Meyer Notch
Uhuru Peak 5895
Great Barranco Gl.
Ratzel Gl.
Heim Gl.
Kersten Gl.
GLACIERS OF NEW GUINEA IN 1936
South Pacific Ocean
Arafura Sea
Noord Wand
Zuid Wand
New Zealand Pass
Carstensz Pyramide
Wollaston Gl.
Van de Water Gl.

1967


INDEX MAP OF
GLACIERS
OF THE
SOUTHERN
HEMISPHERE
VENEZUELA
COLOMBIA
BR. GUIANA
SURINAM
FR. GUIANA
ECUADOR
PERU
BOLIVIA
BRAZIL
PARAGUAY
URUGUAY
ARGENTINA
CHILE
MAP 16.1
MAP 16.2
MAP 16.3
MAP 16.4
MAP 16.5
MAP 16.6
MAP 16.7
MAP 16.8
MAP 16.9
MAP 18.1
MAP 18.2
MAP 18
MAP 17
MAP 15.1
SOUTH AMERICA
South Orkney Is.
South Georgia
South Sandwich Is.
Bouvetøya
McMurdo Sound
ANTARCTICA
Heard
Kerguelen
AFRICA
AUSTRALIA
NEW GUINEA
0 500 1000

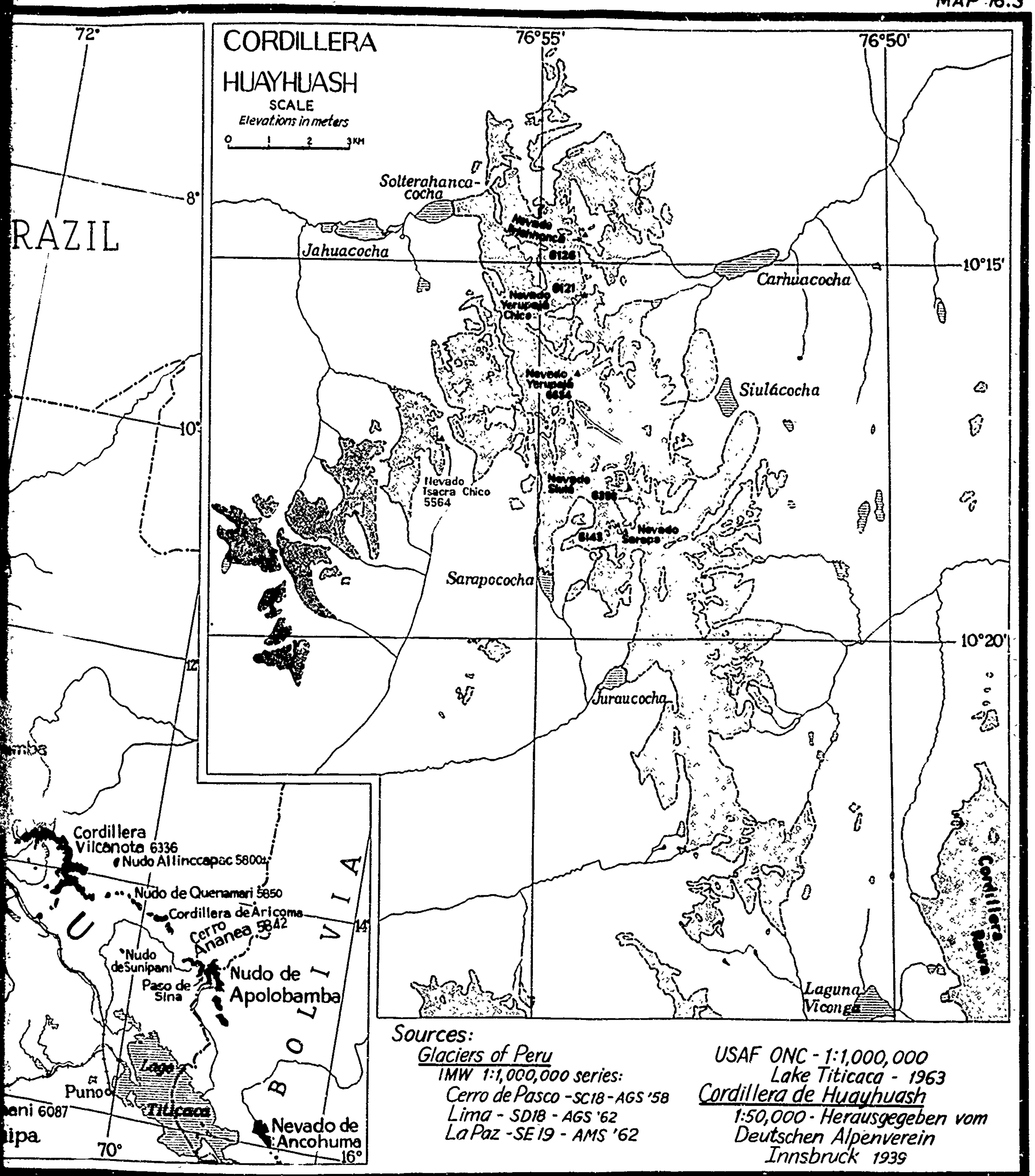

GLACIERS OF ECUADOR
Elevations in meters
Sources:
IMW 1:1,000,000 series
NA17-Rio Mira-Islas Galápagos-AMS 1952
NA18- Cali - AGS 1942
SA17- Quito-AMS 1952
SA18- Iquitos - AGS 1962
Speziallkarte des Chimborazo, 1:60,000
In den Hoch-Anden von Ecuador,
H.Meyer-1903-Map 1, pg. 69
LOCATION MAP
COLOMBIA
Volcán Chiles
Río Mira
Nevado Cotacachi 4937
Ibarra
Río Guallabamba
Cayambe
Volcán Cayambe 5790
Cerro Sara-urcu
Cerro Pichincha 4701
QUITO
Cerro Rumiñahui
Cerro Sincholague 4901
Cerro Antisana 5704
Cerro Corazón 4791
Cerro Iliniza 5305
Volcán Cotopaxi 5896
Cerro Quilindaña 4877
Latacunga
Ambato
Cerro Hermoso 4638
Cerro Carihuairazo 5028
INSET MAP
Chimborazo 6272
Río Pastaza
Volcán Tungurahua 5033
Cajabamba
Riobamba
Cerro Altar 5321
Volcán Sangay
Alausí
Río Upano
Azogues
Cuenca
Carihuairazo
Abraspungo Valley
Chimborazo
Humboldt
Moreno Gl.
GLACIERS OF CHIMBORAZO AND CARIHUAIRAZO 1903
1967


GLACIERS OF THE CORDILLERA BLANCA PERU
Elevations in meters
Q.= Quebrada Nev.= Nevado
LOCATION MAP
Source:
Cordillera Blanca (Peru) · 1:200,000
Herausgegeben vom Alpenverein
Innsbruck · 194?
Huarás
Recuay
Ticapampa
Carhuás
Río Santa
Nevado Huascarán
Nevados Pongos
Río Pativilca


GLACIERS
OF PERU
Elevations in meters
0 100 200 KM.
CORDILLE
HUAYHUAS
SCALE
Elevations in met
BRAZIL
PACIFIC OCEAN
PERU
BOL
8°
10°
12°
14°
16°
78°
76°
74°
72°
70°
Pelagatos Meridional 4928
Nevado Rosko Grande 5188
Cordillera Blanca
Huanuco
INSET MAP
Cordillera Huayhuash
Cerro Huagaruncho
Río Rimac
LIMA
Sierra de Tunshu 5800±
Sierra de Huaytapayana
Huancayo
Ayacucho
Ica
Abancay
Cordillera Vilcabamba 6274
Cuzco
Cordillera Vilcanota 6336
Nudo Allinccapac 5800±
Nudo de Quenamari 5850
Cordillera de Aricoma
Cerro Ananea 5842
Nudo de Sunipani
Paso de Sina
Nudo de Apolobam
Nevado Sara-Sara 5530±
Nevado Solimana 6117
Nevado Coropuna 6425
Nevado Ampato 6310
Chachani 6087
Arequipa
Puno
Lago Titicaca
Nevad Ancoh

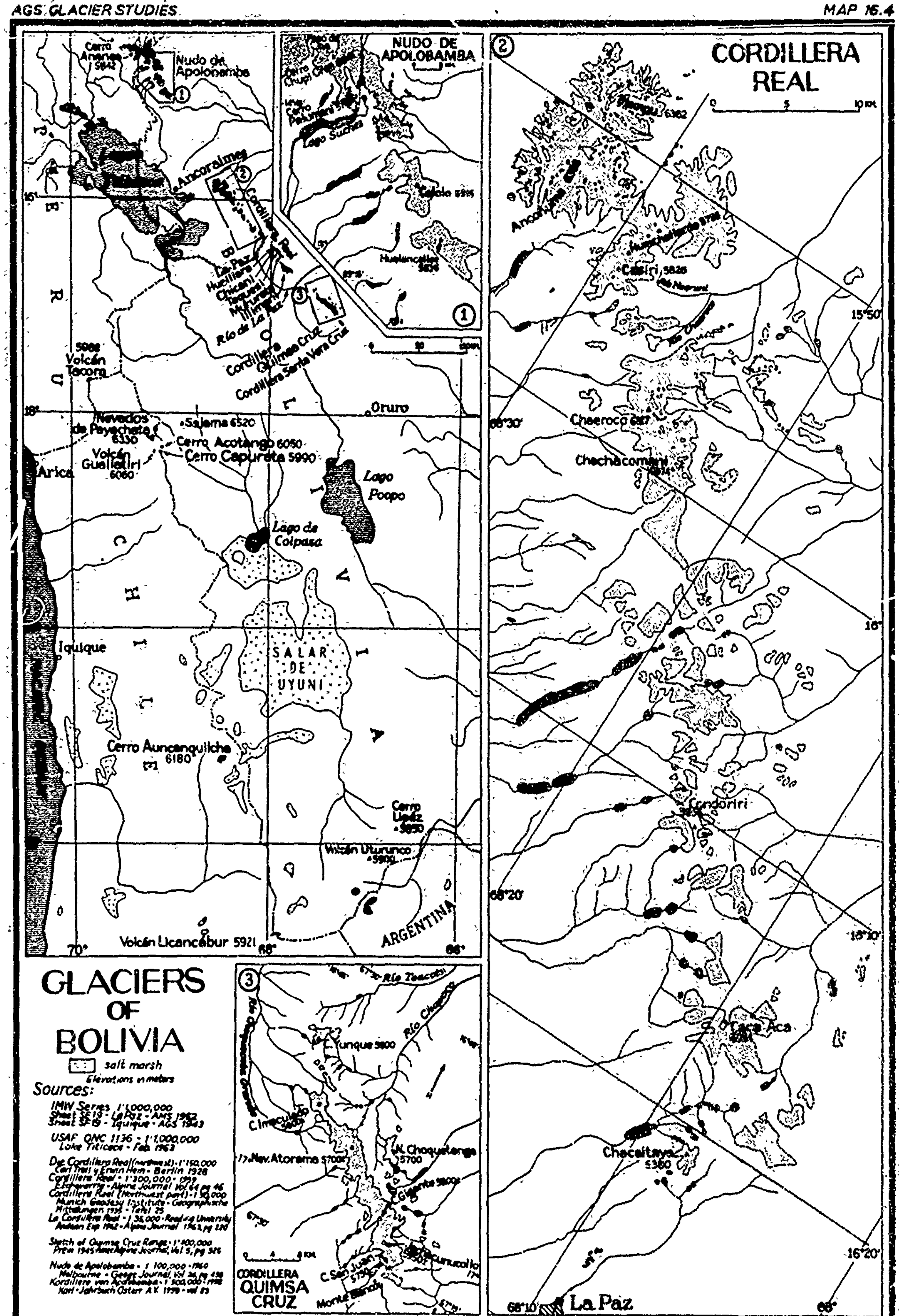
A

MAP 16.3

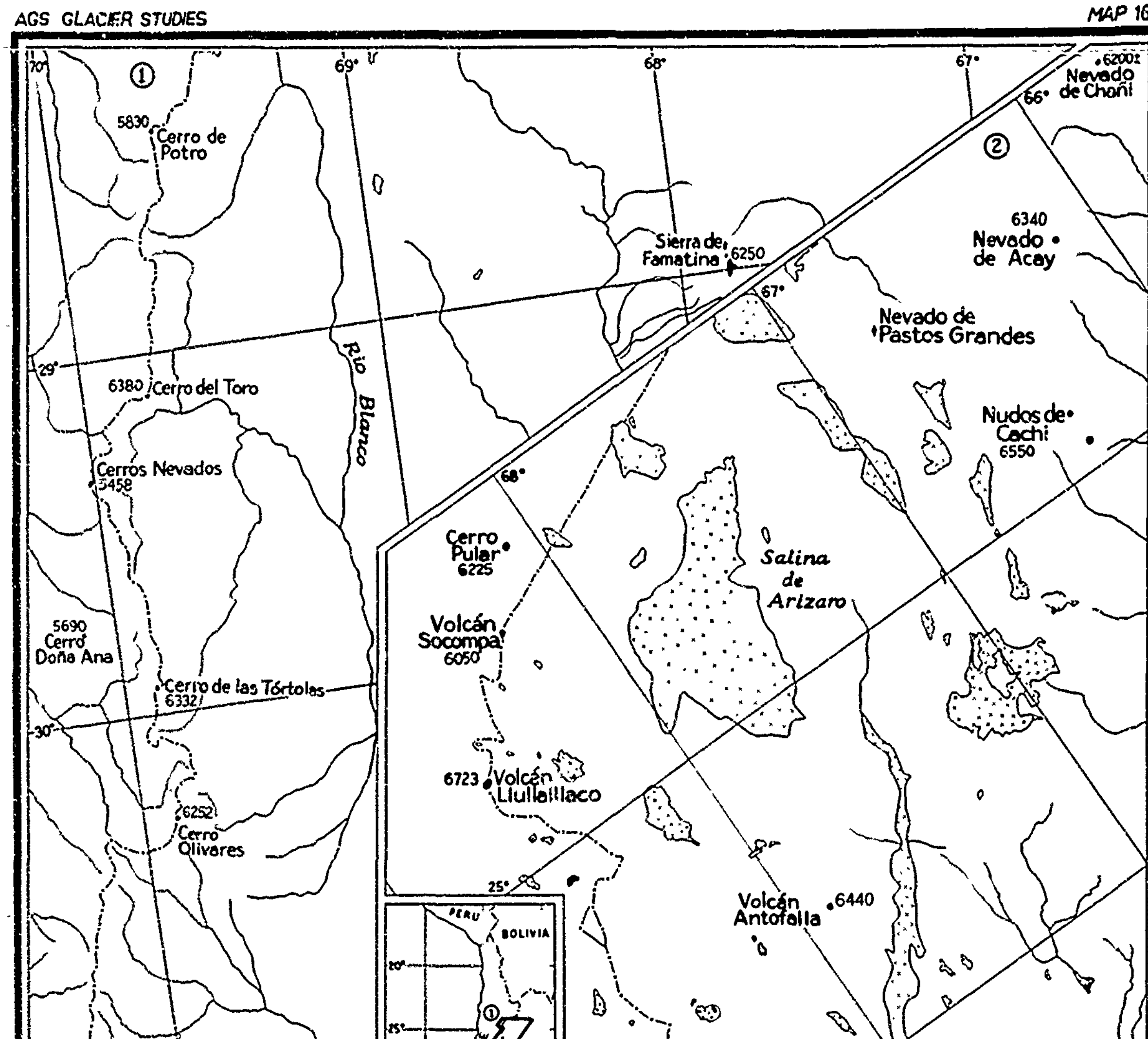


1967

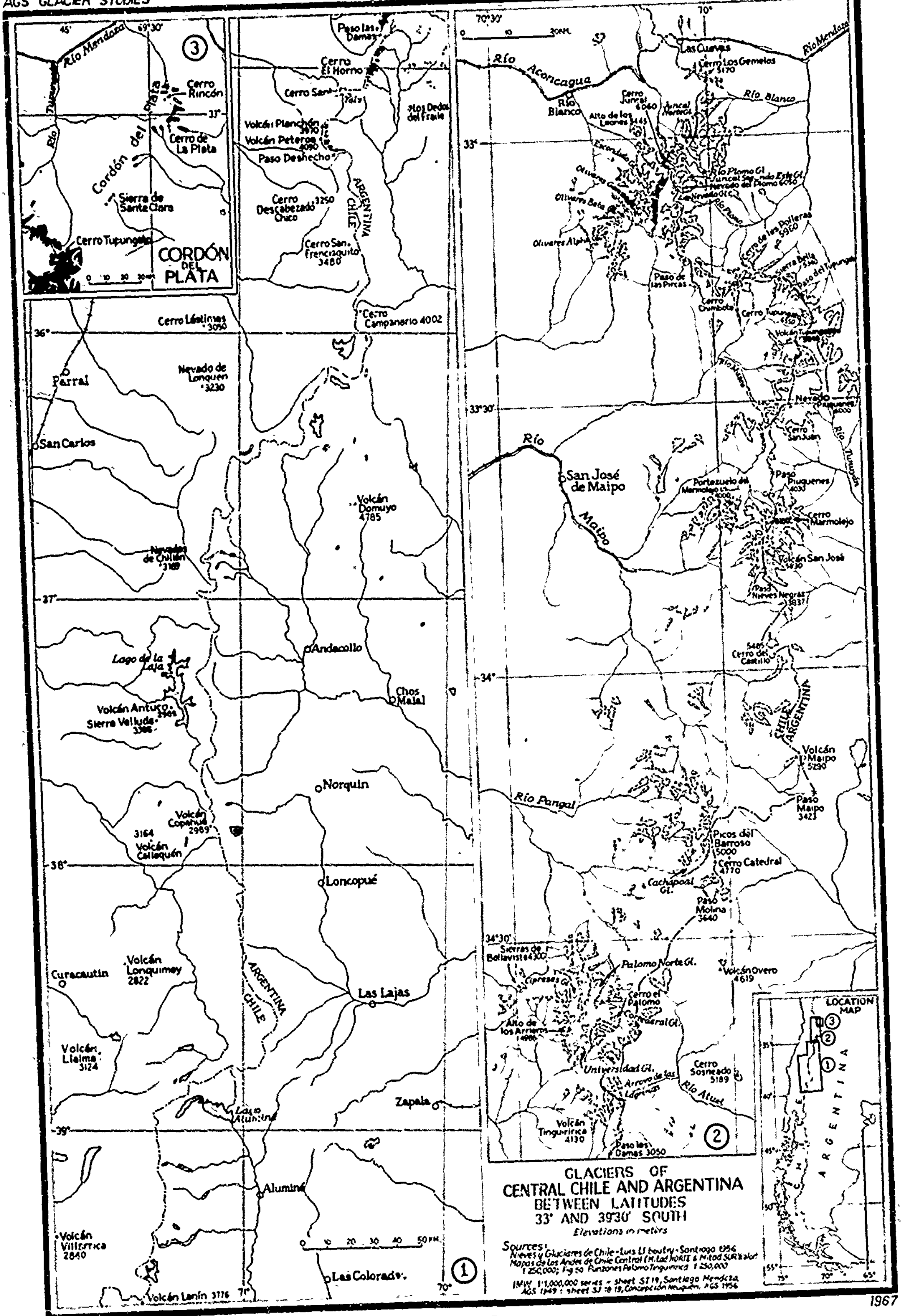
B

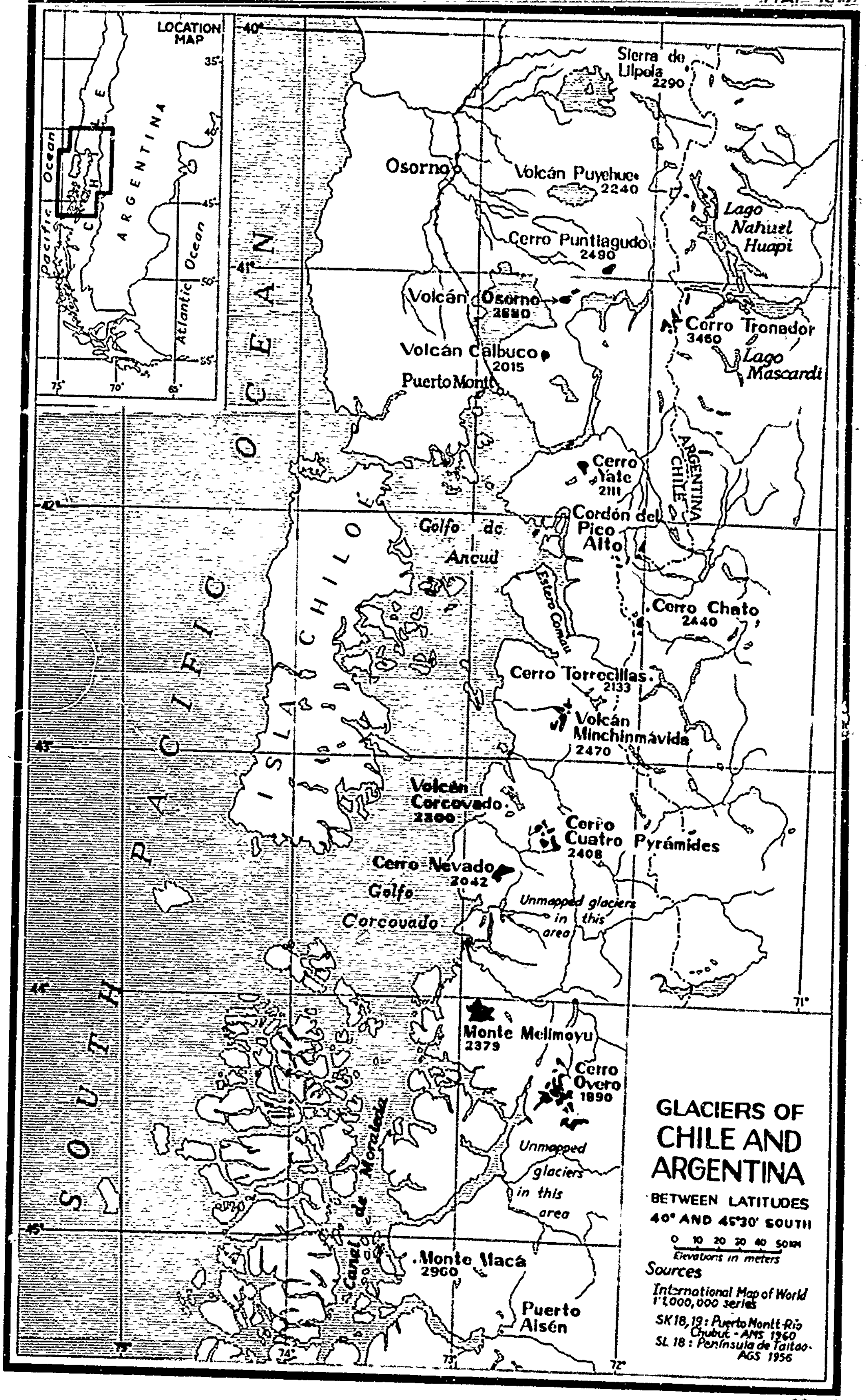

GLACIERS
OF
BOLIVIA
salt marsh
Elevations in meters
Sources:
CORDILLERA
REAL
NUDO DE
APOLOBAMBA
CORDILLERA
QUIMSA
CRUZ
Nudo de Apolobamba
Ancoraimes
La Paz
Oruro
Lago Poopo
Lago de Colpasa
SALAR DE UYUNI
Arica
Iquique
Cerro Auncanquilcha 6180
Volcán Licancabur 5921
ARGENTINA
Volcán Uturunco 5900
Sajama 6520
Cerro Acotango 6050
Cerro Capurata 5990
Volcán Guallatiri 6060
Nevados de Payachata 6330
Volcán Tacora
Cordillera Quimsa Cruz
Cordillera Santa Vera Cruz
Río de La Paz
Chearoco 6127
Chachacomani
Condoriri
Caca Aca
Chacaltaya 5360
Casiri 5828
Ancohuma
La Paz
Huelancalloc
C. Yunque 5600
C. Inmaculado
N. Choquetanga 5700
Nev. Atorama 5700
C. San Juan
Monte Blanco
Río Chicote
Río Tocopaya

1967

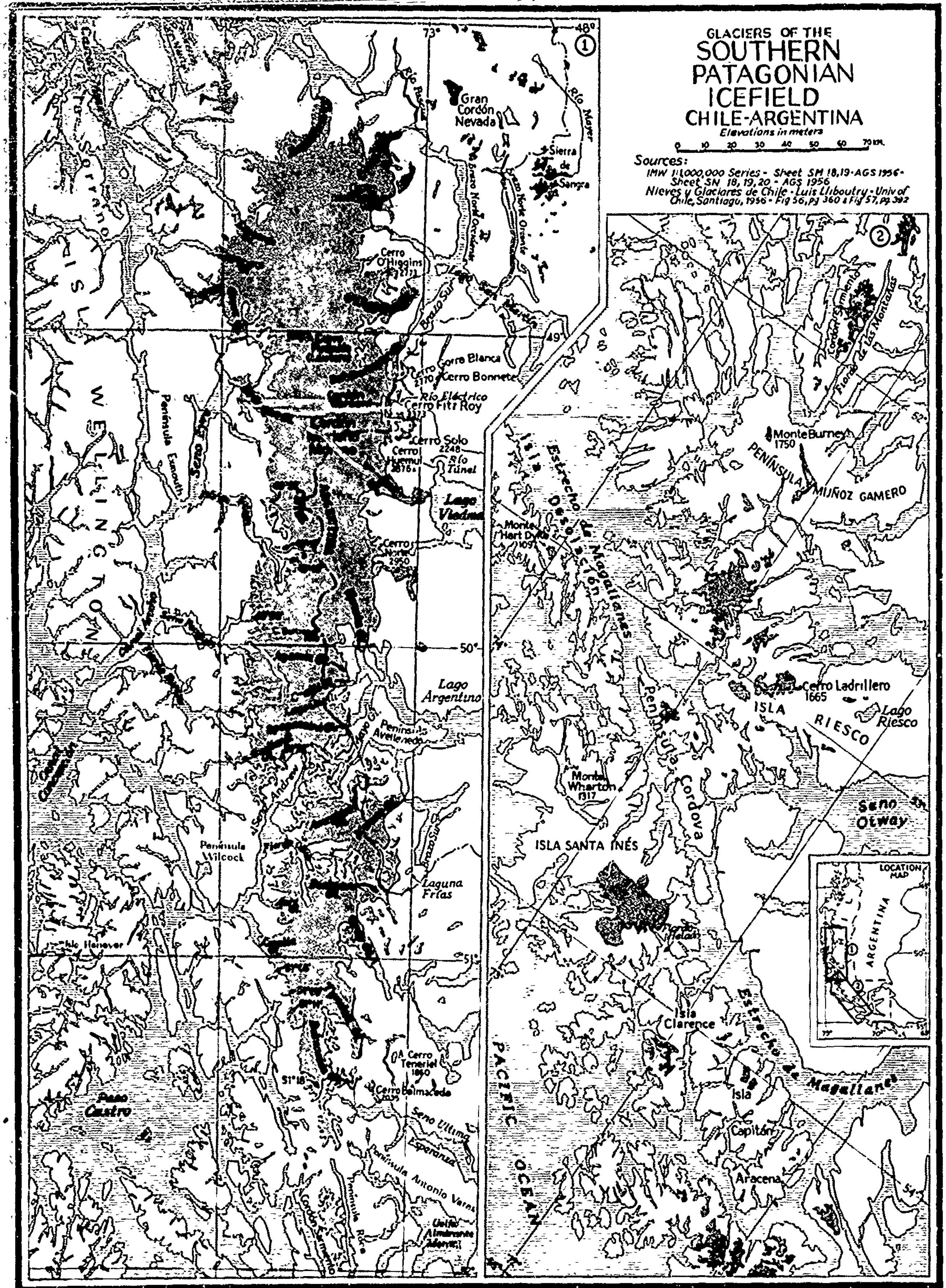

GLACIERS OF
NORTHERN CHILE
AND ARGENTINA
BETWEEN LATITUDES
24° AND 33° SOUTH
Elevations in meters
salt marsh
Sources:
International Map of World
1:1,000,000 series
SG 19 - Atacama - AMS - 4 '61
SH 19 - Coquimbo-San Juan - AGS '42
SI 19 - Santiago Mendoza - AGS '49
5830 Cerro de Potro
Sierra de Famatina 6250
6340 Nevado de Acay
Nevado de Pastos Grandes
6200 Nevado de Chañi
6380 Cerro del Toro
Cerros Nevados 5458
Río Blanco
Nudos de Cachi 6550
Cerro Pular 6225
Salina de Arizaro
Volcán Socompa 6050
5690 Cerro Doña Ana
Cerro de las Tórtolas 6332
6723 Volcán Llullaillaco
6252 Cerro Olivares
Volcán Antofalla 6440
ARGENTINA CHILE
Cordillera de Totora 5620
Cordillera de Ansilta 5900
6400 Sierra Nevada de Lagunas Bravas
Nevado de San Francisco 6020
Cerro Ermitaño 6187
Cerros Peña Blanca 6020
Nevado de Incaguasi 6610
Nevado El Fraile 6060
Nevado El Muerto 6470
Nevado Ojos del Salado 6880
Cerro Solo 6190
Nevs. de Tres Cruces 6330
6637
6250
Cerro de Nacimiento 6493
Cerro de los Patos 6250
6080 Cerro Azufre (Copiapo)
Cerro Pissis 6780
Cerro Bonete 6410
6670 Cerro Mercedario
Cordillera de la Ramada 6410
5600 Cerro Tambillo
Aconcagua 6960
Sierra de Antofalla 6500
PERU
BOLIVIA
CHILE
ARGENTINA

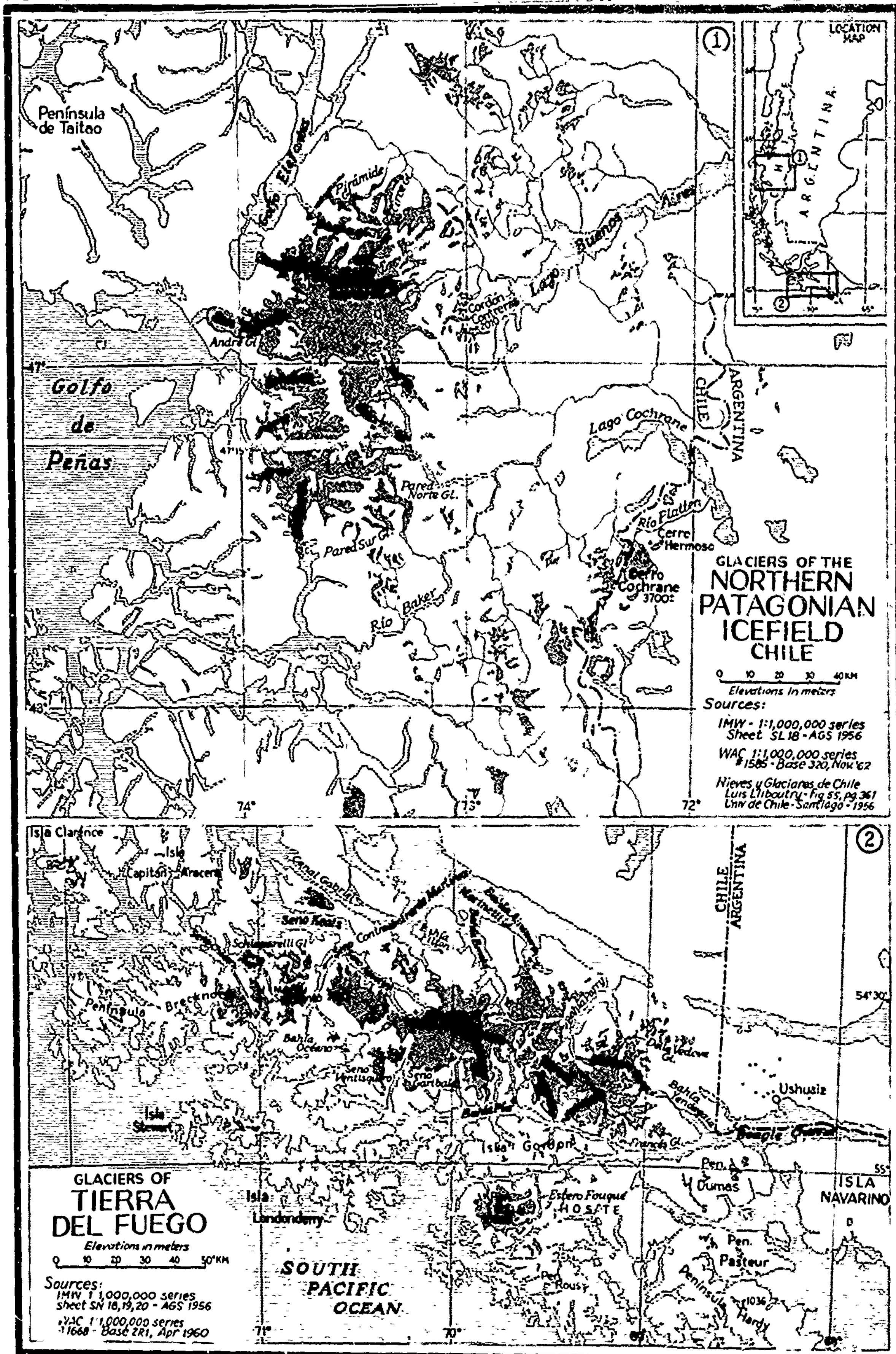
1967

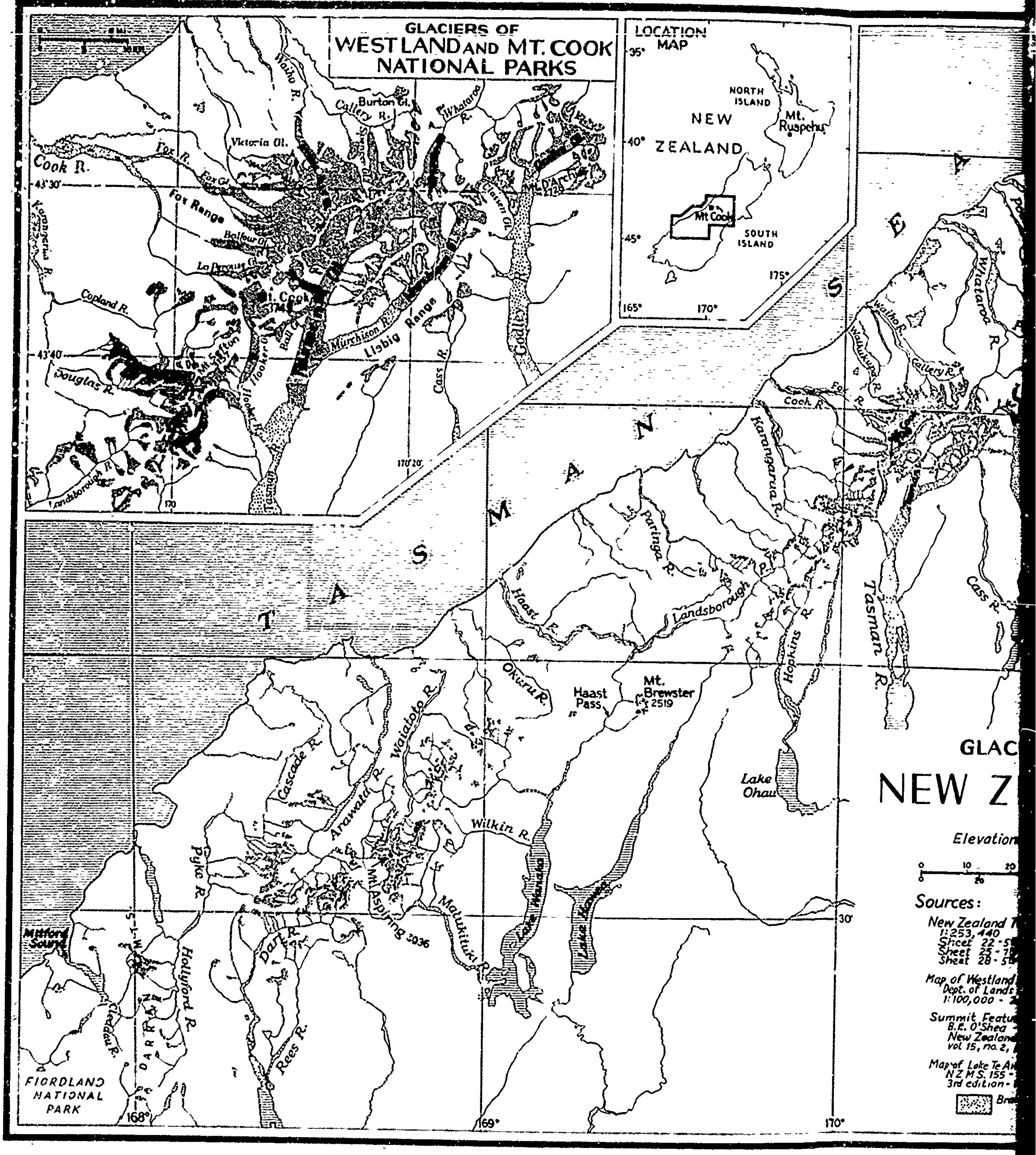

GLACIERS OF
CENTRAL CHILE AND ARGENTINA
BETWEEN LATITUDES
33° AND 39°30' SOUTH
Elevations in meters
CORDÓN DEL PLATA
Cerro Rincón
Cerro de La Plata
Cordón del Plata
Sierra de Santa Clara
Cerro Tupungato
Río Mendoza
Río Tupungato
LOCATION MAP
ARGENTINA
CHILE
Río Aconcagua
Las Cuevas
Cerro Los Gemelos
Río Blanco
Cerro Juncal 6060
Alto de los Leones 5445
Paso de las Pircas
Cerro Chimbote
Cerro Tupungato
Volcán Tupungatito
Nevado Piuquenes
Cerro San Juan
Río Tupungato
Río
San José de Maipo
Maipo
Portezuelo del Marmolejo
Paso Piuquenes
Cerro Marmolejo
Volcán San José
Paso Nieves Negras
Cerro del Castillo
Volcán Maipo 5290
Paso Maipo 3423
Río Pangal
Picos del Barroso 5000
Cerro Catedral 4770
Cachapoal Gl.
Paso Molina 3640
Sierras de Bellavista 4300
Palomo Norte Gl.
Volcán Overo 4619
Cerro el Palomo
Alto de los Arrieros
Universidad Gl.
Cerro Sosneado 5189
Río Atuel
Volcán Tinguiririca 4130
Paso las Damas 3050
Paso las Damas
Cerro El Horno
Volcán Planchón
Volcán Peteroa
Paso Deshecho
Los Dedos del Fraile
Cerro Descabezado Chico
Cerro San Francisquito 3480
Cerro Campanario 4002
Cerro Lástimas 3050
Parral
Nevado de Longuen 3230
San Carlos
Volcán Domuyo 4785
Nevados de Chillán 3169
Lago de la Laja
Andacollo
Chos Malal
Volcán Antuco 2985
Sierra Velluda 3585
Norquin
Volcán Copahue 2969
Volcán Callequén
Loncopué
Curacautín
Volcán Lonquimay 2822
ARGENTINA
CHILE
Las Lajas
Volcán Llaima 3124
Zapala
Lago Aluminé
Aluminé
Volcán Villarrica 2840
Las Coloradas
Volcán Lanín 3776


LOCATION MAP
ARGENTINA
CHILE
Pacific Ocean
Atlantic Ocean
SOUTH PACIFIC OCEAN
ISLA CHILOE
Sierra de Lilpela 2290
Osorno
Volcán Puyehue 2240
Lago Nahuel Huapi
Cerro Puntiagudo 2490
Volcán Osorno 2660
Cerro Tronador 3460
Lago Mascardi
Volcán Calbuco 2015
Puerto Montt
Cerro Yate 2111
ARGENTINA CHILE
Cordón del Pico Alto
Golfo de Ancud
Estero Comau
Cerro Chato 2440
Cerro Torrecillas 2133
Volcán Minchinmávida 2470
Volcán Corcovado 2300
Cerro Cuatro Pyrámides 2408
Cerro Nevado 2042
Golfo Corcovado
Unmapped glaciers in this area
Monte Melimoyu 2379
Cerro Overo 1890
Canal de Moraleda
Unmapped glaciers in this area
Monte Macá 2960
Puerto Aisén
GLACIERS OF CHILE AND ARGENTINA
BETWEEN LATITUDES 40° AND 45°30' SOUTH
0 10 20 30 40 50 KM
Elevations in meters
Sources
International Map of World 1:1,000,000 series
SK18, 19: Puerto Montt-Río Chubut - AMS 1960
SL 18: Península de Taitao - AGS 1956

1967


GLACIERS OF THE
SOUTHERN
PATAGONIAN
ICEFIELD
CHILE-ARGENTINA
Elevations in meters
Sources:
IMW 1:1,000,000 Series - Sheet SM 18,19 - AGS 1956 - Sheet SN 18,19,20 - AGS 1956
Nieves y Glaciares de Chile - Luis Lliboutry - Univ of Chile, Santiago, 1956 - Fig 56, pg 360 & Fig 57, pg 392
Gran Cordón Nevado
Sierra de Sangra
Cerro O'Higgins
Cerro Gorra Blanca
Cerro Bonnete
Río Eléctrico
Cerro Fitz Roy
Cerro Solo
Cerro Huemul
Río Túnel
Lago Viedma
Lago Argentino
Península Avellaneda
Península Wilcock
Laguna Frías
Cerro Tenerife
Cerro Balmaceda
Seno Ultima Esperanza
Península Antonio Varas
Paso Castro
Península Exmouth
WELLINGTON
Monte Burney
1750
PENÍNSULA MUÑOZ GAMERO
Monte Hart Dyke
Cerro Ladrillero
1665
ISLA RIESCO
Lago Riesco
Seno Otway
Monte Wharton
1317
ISLA SANTA INÉS
Península Córdova
Isla Clarence
Isla Capitán Aracena
Estrecho de Magallanes
PACIFIC OCEAN
LOCATION MAP
ARGENTINA

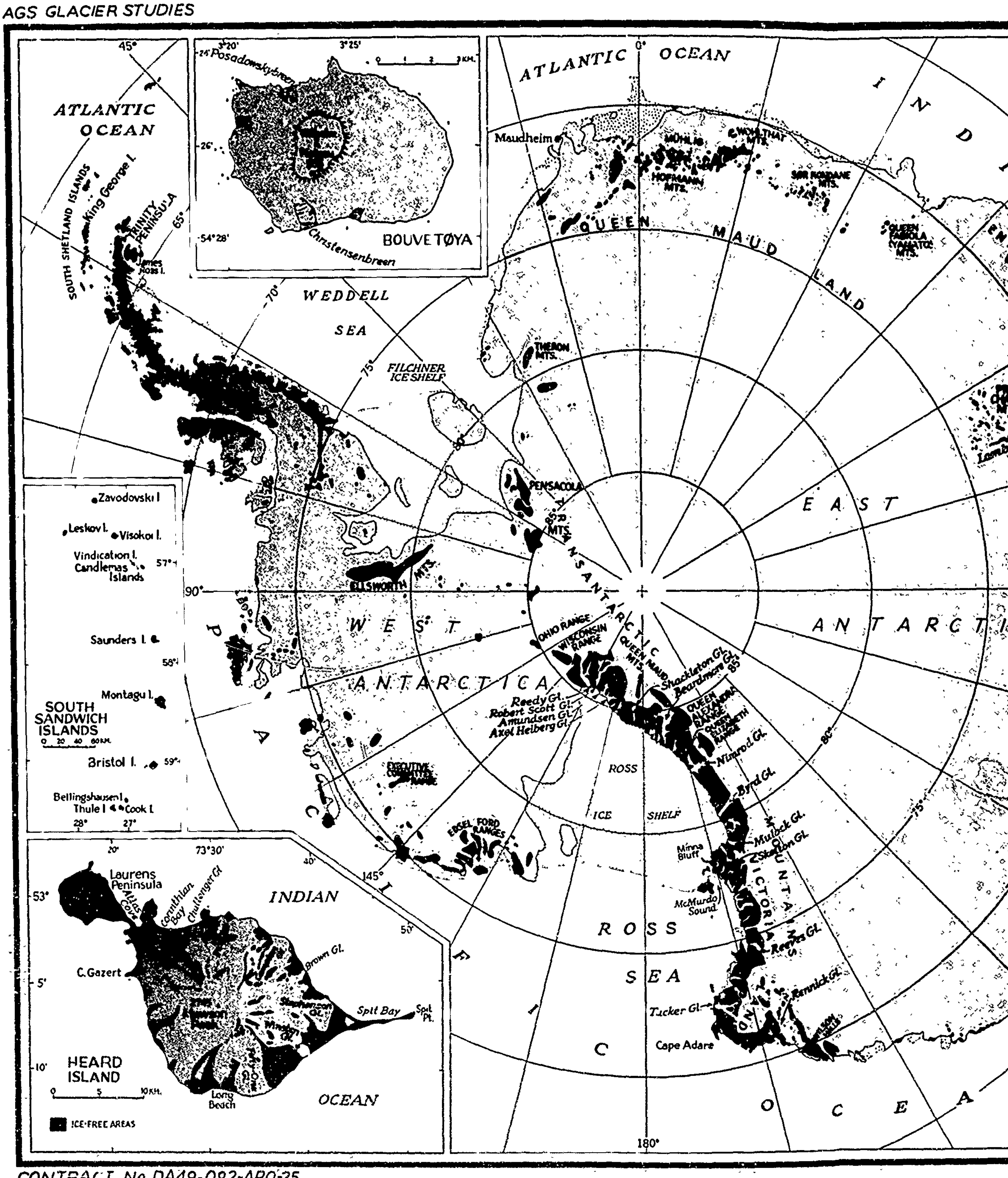

GLACIERS OF THE
NORTHERN
PATAGONIAN
ICEFIELD
CHILE
Elevations in meters
Sources:
IMW - 1:1,000,000 series Sheet SL 18 - AGS 1956
WAC 1:1,000,000 series #1585 - Base 320, Nov '62
Nieves y Glaciares de Chile Luis Lliboutry - Fig 55, pg 361 Univ de Chile - Santiago - 1956
Península de Taitao
Golfo de Peñas
Lago Buenos Aires
Lago Cochrane
Cordón Contreras
Río Baker
Cerro Hermoso
Cerro Cochrane 3700
Pared Sur Gl.
Pared Norte Gl.
CHILE
ARGENTINA
GLACIERS OF
TIERRA
DEL FUEGO
Elevations in meters
Sources:
IMW 1:1,000,000 series Sheet SN 18,19,20 - AGS 1956
WAC 1:1,000,000 series #1668 - Base ZR1, Apr 1960
Isla Clarence
Isla Capitán Aracena
Canal Gabriel
Seno Keats
Bahía Ainsworth
Península Brecknock
Bahía Océano
Seno Ventisquero
Seno Garibaldi
Isla Stewart
Isla Gordon
Ushuaia
Beagle Channel
Pen. Dumas
ISLA NAVARINO
Isla Londonderry
Estero Fouqué
HOSTE
SOUTH PACIFIC OCEAN
Pen. Rous
Pen. Pasteur
Península Hardy


GLACIERS OF
WESTLAND AND MT. COOK
NATIONAL PARKS
LOCATION MAP
NORTH ISLAND
NEW ZEALAND
Mt. Ruapehu
Mt Cook
SOUTH ISLAND
Cook R.
Fox R.
Fox Range
Victoria Gl.
Burton Gl.
Callery R.
Waiho R.
Whataroa R.
Mt. D'Archiac
Balfour Gl.
La Perouse Gl.
Copland R.
Mt. Cook
Murchison R.
Liebig Range
Cass R.
Godley R.
Douglas R.
Mt. Sefton
Hooker R.
Landsborough R.
Tasman R.
T A S M A N
S E A
Karangarua R.
Paringa R.
Haast R.
Landsborough
Okuru R.
Haast Pass
Mt. Brewster 2519
Hopkins R.
Tasman R.
Cass R.
Whataroa R.
Waiho R.
Callery R.
Lake Ohau
Cascade R.
Arawata R.
Waiatoto R.
Wilkin R.
Mt. Aspiring 3036
Matukituki R.
Lake Wanaka
Lake Hawea
Pyke R.
Hollyford R.
Milford Sound
Dart R.
Rees R.
Cleddau R.
FIORDLAND NATIONAL PARK
168°
169°
170°
GLAC
NEW Z
Elevation
Sources:
New Zealand
1:253,440
Map of Westland
Dept. of Lands
1:100,000
Summit Featu
B.E. O'Shea
New Zealand
Map of Lake Te A
N Z M S 155
3rd edition

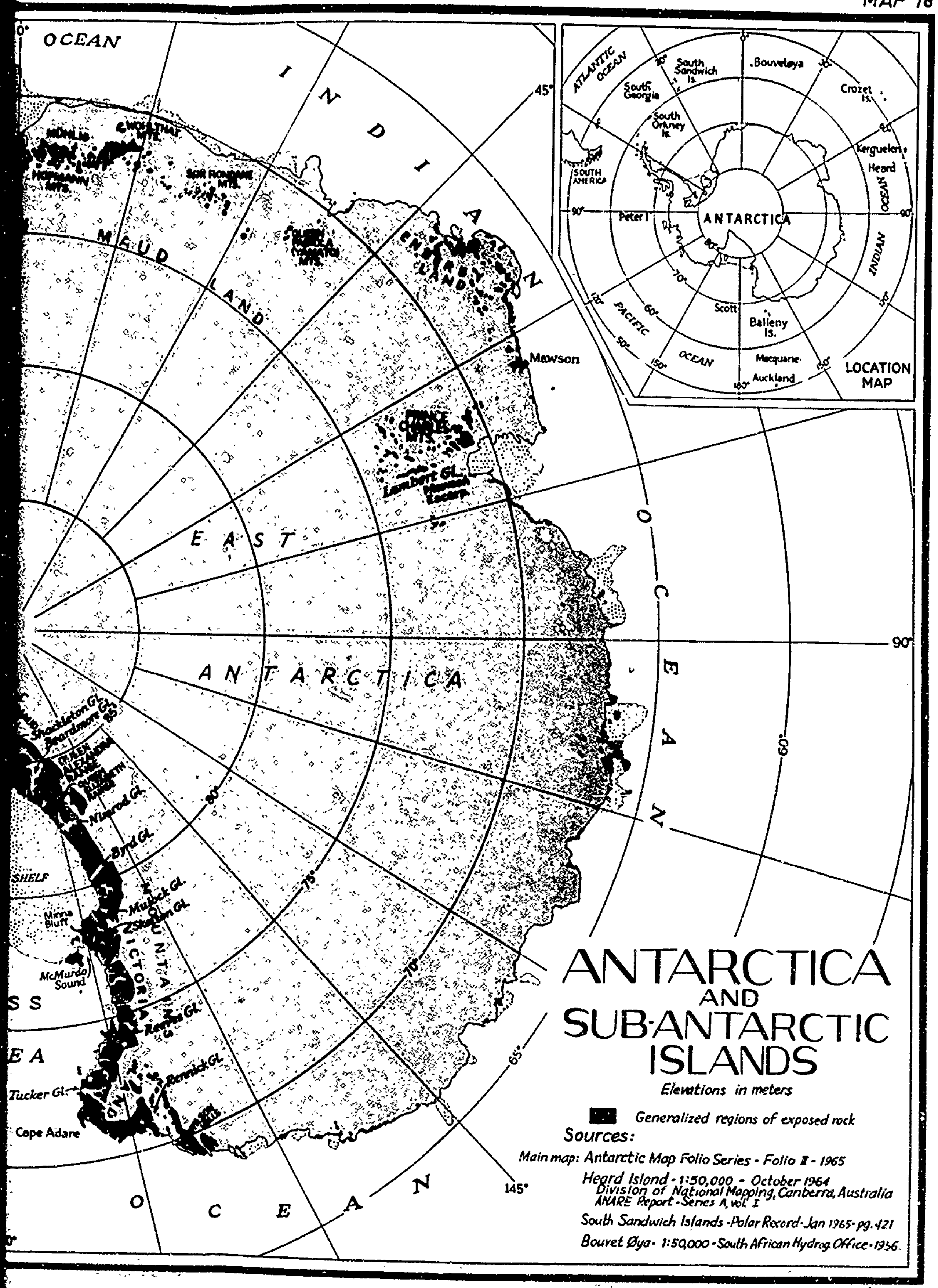

LOCATION MAP
NORTH ISLAND
NEW ZEALAND
Mt. Ruapehu
Mt. Cook
SOUTH ISLAND
175°
170°
Ross
Hokitika R.
Arthurs Pass
Waitaha R.
Whitcombe R.
Waimakariri R.
43°
Poerua R.
Wanganui R.
Mathias R.
Wilberforce R.
Whataroa R.
Rakaia R.
Perth R.
Callery R.
Clyde R.
Lawrence R.
Cameron R.
Cook R.
Fox R.
Havelock R.
Godley R.
30'
Rakaia R.
Karangarua R.
Rangitata R.
Methven
Paringa R.
Ashburton R.
Landsborough R.
Cass R.
Lake Tekapo
Ashburton
Tinwald
Hopkins R.
Tasman R.
Mt. Brewster 2519
44°
Lake Ohau
30'
170°
GLACIERS OF
NEW ZEALAND
Elevations in meters
0 10 20 30 40 50 KM.
0 20 40 60 80 MI.
Sources:
New Zealand Territorial Series
1:253,440
Sheet 22 - 5th ed. - 1 Dec. 1963
Sheet 25 - 7th ed. - 1 Feb. 1963
Sheet 28 - 5th ed. - 1 April 1963
Map of Westland & Mt. Cook National Parks
Dept. of Lands and Surveys, New Zealand
1:100,000 - 2nd edition - Oct. 1961
Summit Features of Ruapehu
B.E. O'Shea - 1959
New Zealand Geographer
vol. 15, no. 2, pgs., 156-159
Map of Lake Te Anau and Environs
N.Z.M.S. 155 - 1:200,000
3rd edition - 1 Mar. 1964
Braided stream bed
175°34'
Te Heu Heu Ridge
Tukino 2715
Te Heu Heu 2735
Paretetaitonga 2750
Nukuhau 2500
39°17'
Mitre Pk. 2575
Tahurangi 2797
GLACIERS OF
MT. RUAPEHU

1967

B


ATLANTIC OCEAN
SOUTH SHETLAND ISLANDS
King George I.
TRINITY PENINSULA
James Ross I.
BOUVET TØYA
Posadowskybreen
Christensenbreen
WEDDELL SEA
FILCHNER ICE SHELF
Maudheim
QUEEN MAUD LAND
HOFMANN MTS.
SØR RONDANE MTS.
THERON MTS.
PENSACOLA MTS.
ELLSWORTH MTS.
WEST ANTARCTICA
EAST ANTARCTICA
OHIO RANGE
WISCONSIN RANGE
QUEEN MAUD MTS.
Shackleton Gl.
Beardmore Gl.
Reedy Gl.
Robert Scott Gl.
Amundsen Gl.
Axel Heiberg Gl.
Nimrod Gl.
Byrd Gl.
ROSS ICE SHELF
EXECUTIVE COMMITTEE RANGE
EDSEL FORD RANGES
Minna Bluff
Mulock Gl.
Skelton Gl.
McMurdo Sound
VICTORIA LAND
ROSS SEA
Reeves Gl.
Rennick Gl.
Tucker Gl.
Cape Adare
PACIFIC OCEAN
Zavodovski I.
Leskov I.
Visokoi I.
Vindication I.
Candlemas Islands
Saunders I.
Montagu I.
SOUTH SANDWICH ISLANDS
Bristol I.
Bellingshausen I.
Thule I.
Cook I.
Laurens Peninsula
Atlas Cove
Corinthian Bay
Challenger Gl.
INDIAN OCEAN
Brown Gl.
C. Gazert
Spit Bay
Spit Pt.
Stephenson Gl.
Winston Gl.
HEARD ISLAND
Long Beach
ICE-FREE AREAS
180°

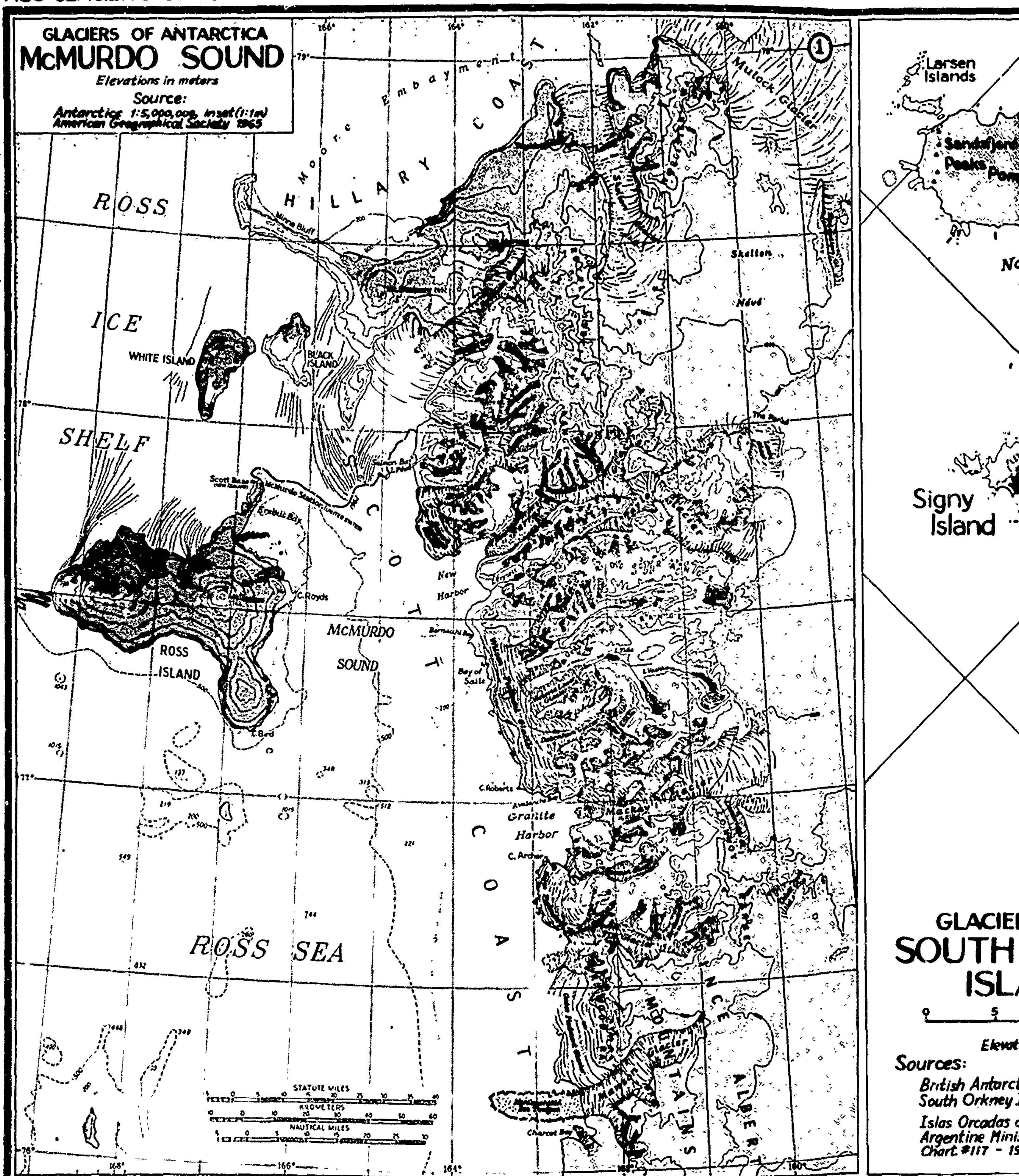
A



ANTARCTICA
AND
SUB-ANTARCTIC
ISLANDS
Elevations in meters
Generalized regions of exposed rock
Sources:
Main map: Antarctic Map Folio Series - Folio II - 1965
Heard Island - 1:50,000 - October 1964
Division of National Mapping, Canberra, Australia
ANARE Report - Series A, vol. I
South Sandwich Islands - Polar Record - Jan 1965 - pg. 421
Bouvet Øya - 1:50,000 - South African Hydrog. Office - 1956.
LOCATION
MAP
ANTARCTICA
ATLANTIC OCEAN
South Sandwich Is.
South Georgia
South Orkney Is.
SOUTH AMERICA
Bouvetøya
Crozet Is.
Kerguelen
Heard
INDIAN OCEAN
PACIFIC OCEAN
Peter I
Scott
Balleny Is.
Macquarie
Auckland
OCEAN
I N D I A N
O C E A N
MAUD LAND
ENDERBY LAND
Mawson
PRINCE CHARLES MTS.
Lambert Gl.
E A S T
A N T A R C T I C A
Shackleton Gl.
Beardmore Gl.
Nimrod Gl.
Byrd Gl.
SHELF
Minna Bluff
McMurdo Sound
Mulock Gl.
VICTORIA
Reeves Gl.
Rennick Gl.
Tucker Gl.
Cape Adare
O C E A N
45°
90°
60°
65°
70°
75°
80°
85°
145°

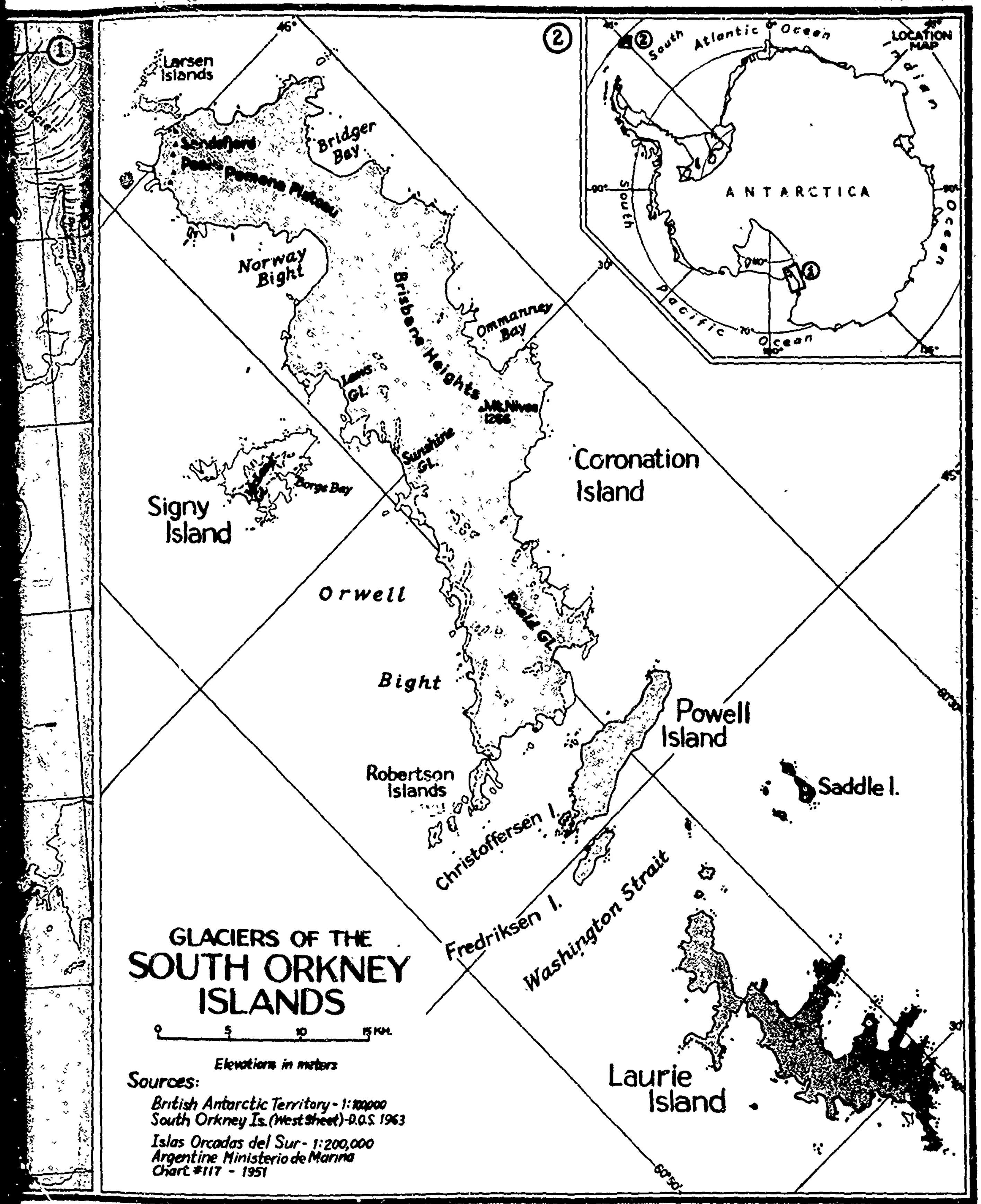
1967

B


GLACIERS OF ANTARCTICA
McMURDO SOUND
Elevations in meters
Source:
Antarctica 1:5,000,000, inset (1:1m)
American Geographical Society 1965
1
ROSS
ICE
SHELF
WHITE ISLAND
BLACK ISLAND
Minna Bluff
Moore Embayment
HILLARY COAST
Mulock Glacier
Skelton
Névé
Scott Base
McMurdo Station
Erebus Bay
C. Royds
ROSS ISLAND
C. Bird
New Harbor
McMURDO SOUND
Bay of Sails
C. Roberts
Granite Harbor
C. Archer
SCOTT COAST
ROSS SEA
ALBERT MOUNTAINS
Charcot Bay
STATUTE MILES
KILOMETERS
NAUTICAL MILES
Larsen Islands
Signy Island
GLACIER
SOUTH
ISLA
Sources:
British Antarct
South Orkney I
Islas Orcadas d
Argentine Minis
Chart #117 - 19

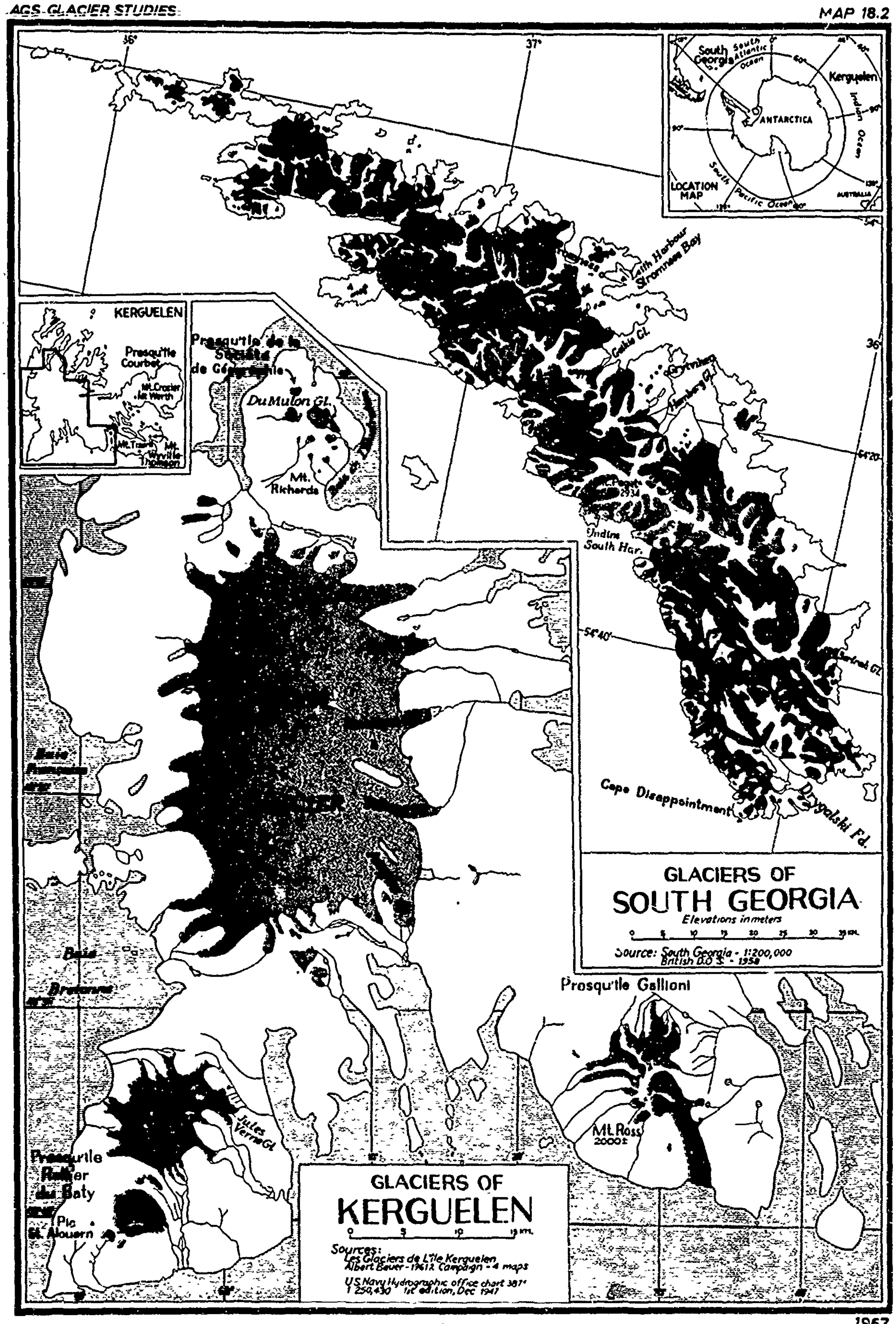
A

MAP 18.1



1967

β


GLACIERS OF
SOUTH GEORGIA
Elevations in meters
Source: South Georgia - 1:200,000
British D.O.S. - 1958
Stromness Bay
South Harbour
Cape Disappointment
Drygalski Fd.
Central Gl.
Undine
South Har.
LOCATION MAP
ANTARCTICA
Kerguelen
South Georgia
KERGUELEN
Presqu'ile Courbet
Mt. Wyville Thomson
Presqu'ile de la Société de Géographie
Du Mulon Gl.
Mt. Richards
Prosqu'ile Gallioni
Mt. Ross
2000±
Jules Verne Gl.
Pic St. Alouarn
GLACIERS OF
KERGUELEN
Sources:
Les Glaciers de L'ile Kerguelen
Albert Bauer - 1961 Campaign - 4 maps
U.S. Navy Hydrographic office chart 3871
1:250,430 1st edition, Dec 1947

Unclassified

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5. AUTHOR(S) (Last name, first name, initial)

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This study is a literature survey of knowledge on mountain glaciers in the Southern Hemisphere. The Southern Hemisphere is divided into the following regional categories with respect to glaciers: (1) The Andes of South America, (a) Ecuador, (b) Peru, (c) Bolivia, (d) Chile, and (e) Argentina, (2) New Guinea, (3) East Africa, (4) Sub-Antarctic Islands, (5) New Zealand, and (6) Antarctica. Included are discussions on the distribution, extent, characteristics, and behaviour of mountain glaciers and an extensive list of references for each regional discussion. A history of observations and current research programs is incorporated in the text. Nineteen new maps have been prepared on the mountain glaciers in the Southern Hemisphere.

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
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Area	8					
Characteristics	8					
Glaciers	9					
Mountains	9					
Southern Hemisphere	9					

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